Antennas
Prof. Girish Kumar
Department of Electronic Engineering
Indian Institute of Technology, Bombay

Module - 11
Lecture - 51
Yagi-Uda and Log-Periodic Antennas-II

Hello and welcome to today's lecture on Yagi-Uda antenna as well as log periodic antenna. In fact, in the last lecture, we had discussed about Yagi-Uda antenna and we saw that by adding more number of directors, we can increase the gain of the antenna and we also saw very simple technique how to feed a dipole antenna. So, that we do not require extra Balun. Now we will talk about today how to increase the bandwidth of the Yagi-Uda antenna. So, it is a very strange thing. In fact, Yagi-Uda antennas were originally designed for higher gain and log periodic antennas were originally designed for broadband antenna, but as we say you know we are never satisfied, we always want something more, we always want that it is like it says [FL]. So, in Yagi-Uda antenna also so people were able to get a higher gain but bandwidth was always a limitation.

Today we will talk about Yagi-Uda antenna, how these are modified to obtain broad bandwidth. So, we will start with the first configuration which is a broadband quasi Yagi-Uda antenna. So, let us see why we call it a broadband quasi.

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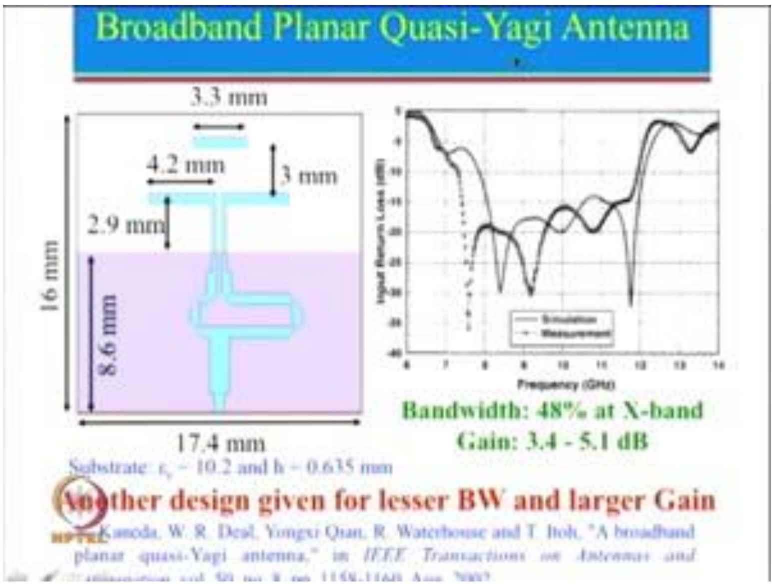

Let us start with the presentation. So, we are starting with a broadband planer quasi Yagi antenna. So, what we really have here. So, let us just see this particular antenna has been actually designed around X-band. So, you can see here the frequency centre frequency is around 10 gigahertz or so. So at 10 gigahertz, what will be the wavelength? That will be 30 mm, so what will be half of that which will be 150 mm, but what you see over here is much lesser than that over here.

See the dipole length half of that is about 4.2 here, another half is about 4.2. So, the total length is actually much smaller than the half wavelength which is coming to be about 15 mm. The reason for that is the substrate chosen over here has a very high dielectric Constance. So, epsilon R here is about 10.2 and the thickness of the substrate is given by 0.635 because of the larger value of the epsilon R large amount of field is confined within this particular high value of epsilon R and hence effective dielectric Constance increases which reduces the overall length here. So, you can see that this is a normal dipole antenna, but the feed over here looks different. So, let me explain, how it has been obtained and all these things have been taken from this particular paper which appeared in about August 2002. So, here is the feed point and that feed point you can see here is divided into 2 parts.

Now, why because here you need to feed this with let us say 1 angle 0, we want to feed this with let us say 1 angle 180 degree. So, you can say plus 1 and minus 1. So, we need a phase difference between the 2 to be equal to 180 degrees. So, you can see from here power divide is divided equally. So, one path goes over here and another one is going over here, you can see this length is much larger than this length because this length actually is lambda by 2 larger then this length over here and that additional lambda by 2 length provides 180 degrees phase shift. So, you can see over here and then you can also see that the line widths are slightly different because it is a quarter wave transformer has been used to do the impedance matching. So, that is what is this part here and then you can see here this is going here feeding with equal power and opposite phase difference.

Now, concept is slightly different you can actually see here that power is fed from this particular point. So, from here, it is divided into 2 parts. So, one path is going like this here and then another path is going like this here and you can see that this path is much longer than this path, the reason for that is we need to feed this dipole antenna with let us say 1 angle 0 and this has to be 1 angle 180 degree. So, that 180 degree phase difference is provided by additional lambda by 2 length. So, when we divide from here, equal power is divided in the 2 path here so; that means, let us say amplitude will be a angle 0 and this will be a angle 180 degree or we can say it is minus a. So, the dipole will we get equal amplitude and out of phase feed here and you can also see here that the width of these lines are not same that is mainly to do the impedance matching you can see over here this is nothing, but a quarter wave transformer which has been used to transform the impedance for matching with the 50 ohm line.

Now, the reason why it is known as quasi because it is not really using the concept of the Yagi, what was the concept of the Yagi, it has a 1 reflector antenna then it has a driven element then it has a director and there were space at lambda by 4 distance and there the idea was to provide 1 angles 0, 1 angle 90 degree and then 1 angle minus 90 degree on either side which radiates in the you can say in the end fire direction, but over here the concept of Yagi-Uda is done, but it has been optimized for larger bandwidth. So, here the parasitic patch which is over here this has been optimized in such a way that this particular thing over here excides get coupled to it and because of the coupling there will be a loop in the smith chart of course, here we can only see the input return loss. So, one can actually say here simulated and measure and one can actually see this has a very large bandwidth you can see that this is the minus dB line here and you can actually see from here bandwidth is very large it is almost 48 percent at expand.

Normally Yagi antennas are not supposed to give 48 percent. So, it is actually specially optimized to get larger bandwidth, but it is at the expensive decrease in the gain you can see that even though it has a very large reflector ground plane is acting like this, this is at a dipole antenna and even if it has a director; if it was the original case of Yagi-Uda, gain would have been much larger, but here optimization has been done mainly for the large bandwidth hence gain is relatively small from 3.4 to 5.1 dB within this particular band; however, in the same paper, they have given an another design where they have optimized this whole thing for larger gain, but for larger gain then they got a lesser bandwidth and this bandwidth was much smaller compared to the bandwidth over here and that would be more closer to them Yagi-Uda antenna which gives normally a larger gain, but smaller bandwidth so; that means, depending up on the requirement these dimensions can be optimized either to get larger gain or to get larger bandwidth.

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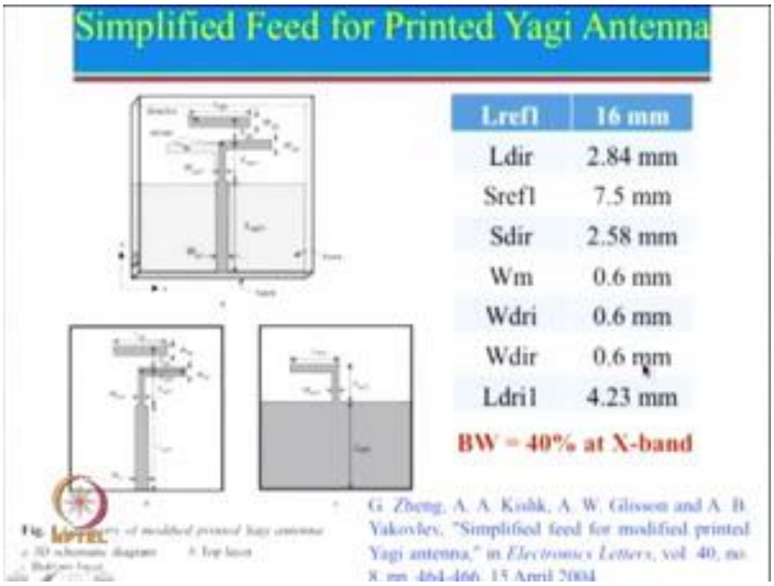

Now, let us look at another configuration. So, here the feed configuration is relatively simple. Now the earlier paper was published in 2002, this paper came a few years later and probably they studied that configuration and then did the simplified feed network. So, let us see how the feed network has been simplified. So, here there is a ground plane which is on the back side and you can see that this is the top one and you can see this is the strip which is directly connected to the one-halfth of the dipole antenna then you can see this is the top view you can see the top view will be nothing, but this micro step line and then that is connected to this arm of the dipole and then there is a you can say parasitic element.

Now, over here the backside; backside will consists of this ground plane and you can actually see that there is a line going like this over here. So, that is the line. So, this if you super impose you will get this configuration. So, here the emphasis was that the feed network is relatively much simpler compared to the previous case where they had used the power divided network and then additional lambda by 2 length here that part has been simplified the rest of the concept remains similar and here in this case they got the bandwidth of about 40 percent at X-band and this is the paper. So, earlier paper came in 2002 this came in 2004 and you can actually see these are the different dimensions of the antenna then let us just look at another configuration.

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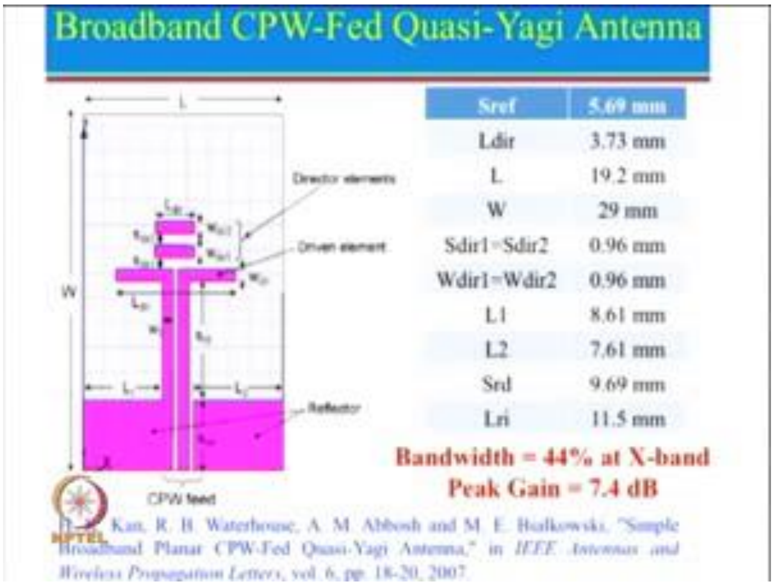

Now, this one here again has a different feed network and it has one more director also, let us just start with the feed network here. So, what this is? This concept is known as this CPW feed where this one and this one; these 2 act like a ground plane and this one here is the central fin, just think about a coaxial feed. So, in the coaxial feed generally what we have we have a centre pin and then along that centre pin in the circular manner the coaxial feed is actually there, here just think about instead of have a ground plane in the circular fashion, now we only in this side and this side.

So, what we need to do it is we need to connect this and this and generally these 2 are connected. So, if we connect a SME connector over here for example, so, the SME connector; the metallic portion is holded here and here which will actually form combined ground plane and the centre pin of this SME connector is connected here. So, that is how this particular feed is done and again you can see that you do not need a power divider network or so and also the advantage of this configuration is everything is printed on one side of the substrate only, there is a no backside. So, backside no printing has to be done so; that means, no alignment also has to be done. So, here what we can see here. So, the centre pin is going here feeding the one half of the dipole antenna and the ground one here is connected to the other part of the dipole antenna.

Now in this particular case, you can see now, there are parasitic elements and you can see these parasitic elements are very small compared to the fed dipole antenna unlike in the Yagi-Uda antenna, generally this dimension is somewhat comparable to the fed element and also these are generally spaced at lambda by 4 distance, but here these are very close because the reason is here again it has been optimized for larger bandwidth. So, that is why the name Quasi Yagi antenna is here it uses the concept of Yagi, but not really complete Yagi. So, that is why Quasi and this is a CPW feed here. So, in this particular case, we have been able to obtain a bandwidth of 44 percent at X-band, you can see that in the previous cases also, we got a bandwidth of the order of 40 to 48 percent. So, it is similar to that, but here because of this additional thing, the gain peaks is around 7.4 dB, but please remember, this is a peak gain and not the gain over the entire bandwidth, now this paper came in around 2007.

Now, similarly there are lot of other cases are there for Yagi-Uda antenna. So, just to mention here, there are Yagi-Uda antennas. So, which actually let us say this is a normal Yagi-Uda. So, in between they will put a smaller duel band Yagi-Uda antennas also; that means, in the same space what they do let us say we have a one reflector then let us say we have dipole and then we have a director. So, this one will operate at one frequency then let us say the smaller version of that which is this is a smaller version and this will be put in between these things. So, this will actually like a second band. So, that is how a dual band Yagi-Uda antenna have been also realized.

Then there are many Yagi-Uda antennas what they also do they actually utilize this concept this one will give us one polarization and in this case see a dipole gives vertical polarization, but if you see like this now it is horizontally polarizing. So, what they do they use the elements like this fashion and then they use perpendicular to that also. So, the array is also put like this here. So, by putting this particular thing they can get the dual polarized Yagi-Uda antenna; however, I do not recommend very strongly these orthogonally polarized Yagi-Uda antenna. In fact, instead of that one can actually use a let us say a rectangular micro step antenna or circular micro step antenna and then you can feed the 2 orthogonal point and you can get a desired polarization.

Yes, one can use either 2 Yagi-Uda antennas perpendicular to each other or you can use the modified version of micro step antenna or you may say that micro step antenna will be this one occupies lesser you can say overall space is still large, but it has a lot of vacant spaces and then window loading will be relatively less that is the argument we have heard before, but actually speaking instead of that what you can do instead of using a let us say a rectangular micro step antenna or if they want a same frequency dual band then one can use a square micro step antenna with 2 feed, but that will block the whole thing. So, instead of that one can actually use a cross shape I have shown you a cross shape micro step antenna also. So, if one uses a cross shaped antenna it will almost look similar to this and but the feed network will be very simple you just need to feed here and feed over there. So, one can actually use modified micro step antenna there also if you want to get a larger bandwidth you can use the concept of the stacked configuration to realize a larger bandwidth also.

Now we will go to the next topic which is a log periodic antenna and as I mentioned in my introductory thing, Yagi-Uda antennas were originally designed for higher gain and log periodic antennas were originally designed for broadband width, but we did see that in the last one decade people are working on Yagi-Uda antennas or rather I would say quasi Yagi-Uda antennas to increase the bandwidth, but now we will talk about log periodic antennas and log periodic antennas actually speaking can give bandwidth from let us say 1 gigahertz to 10 gigahertz or let us say 300 megahertz to 3 gigahertz.

1 is to 10 bandwidth can be very easily achieved using log periodic antenna. In fact, I will also show you one design example where they have almost got 10 is to 15 ratio also. So, let us start with the log periodic antenna.

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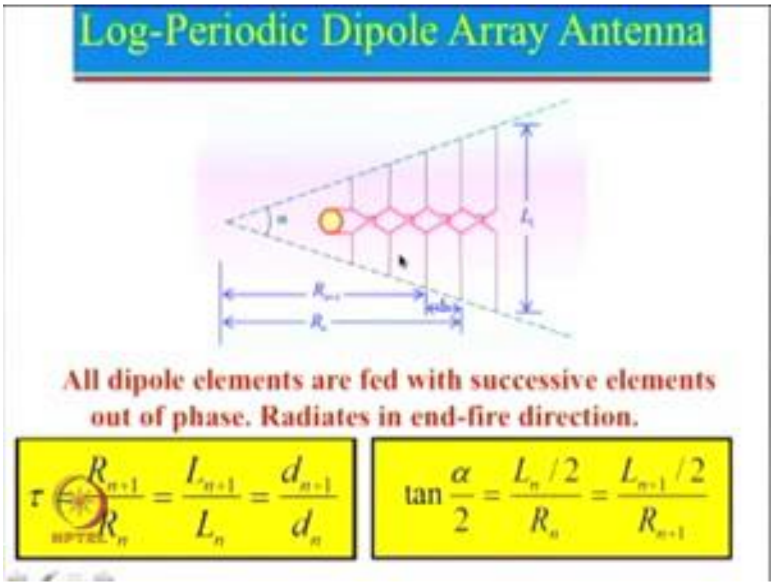

This configuration here shows a log periodic dipole array antenna. So, instead of dipole element many other variations have also been used, but this is one of the most popular one. So, I will focus on the dipole array elements here. So, what we have here let us start with. So, we have a one dipole antenna we have another dipole antenna we have another dipole antenna we have another. So, we have n number of dipole antennas over here and you can actually see that these dipole lengths are arranged in such a fashion that if you extend this here they meet at this particular point. So, basically you can say that the dipole dimensions are varying in the angular fashion. So, instead of dipole antenna as I said other things are also possible, but this is the by far the most popular one here.

Now what we have the next is the feed network. So, you can actually see that this is the feed here. So, that feed you can see is connected over here and since these are dipole antenna we need a balance feed. So, let us assume right now it is one angle 0, one angle 180 degree then we will see also how Baluns can be designed, but now what we can see is that this dipole antenna now this feed is actually connected over here and this one is connected over there. So, you can call it a cross connection, but the purpose of the cross connection is to provide 180 degree phase shift between this and this and then from here to here you can again see there is a phase shift of 180 degree then there is a phase shift of 180 degree.

Let us just see quickly, what is the difference between Yagi-Uda and log periodic antenna? So, in case of Yagi-Uda antenna, reflector antenna was slightly larger than the driven and then there were director element director elements of generally of the same length, but over here all the dimensions are varying in the angular fashion. In fact, I will use the term in the logarithmic fashion and we will see how the logarithmic thing comes into picture, but what we also want to mention over here that in case of the Yagi-Uda antenna, we generally have a spacing of about lambda by 4 and we had seen that for lambda by 4 spacing and for end fire radiation the phase difference between the element should be 90 degree, but in case of the log periodic antenna as we saw that the phase difference between the element is about 180 degree. So, for 180 degree what we need is that the spacing between the elements should be approximately lambda by 2. So, it is different than Yagi-Uda there the spacing between the elements was generally lambda by 4 here we take generally as lambda by 2.

Then comes the next point which lambda we should take because here if you are talking about a broadband log periodic antenna and as I just mentioned the ratio can be 1 is to 10 or 1 gigahertz to 10 gigahertz then the question is we should take lambda for which value 1 gigahertz or 10 gigahertz. So, I will just tell you the spacing also varies in the log periodic manner. So, let us see the figure once again. So, here we just talked about the dipole antenna which are multiple of them are there and which are fed with 180 degree phase difference. So, now, the length of these dipole antennas varies as a ratio top. So, these are known as a ratio or scaling factor term and let us just first talk about the length.

Now, here I just want to mention I have shown here this length as L 1 which is the largest length and then this is L 1 L 2 and it will go to L n, but there are some books where they have mentioned this length as L n and they start from here L 1. So, please do not get confused. So, just remember here in this case we are taking the length which is largest 1 as L 1 smallest 1 is L n and then similarly now these are the from the you can say apex point these are the distances which is given by R. So, you can say from here to here, it will be R 1 then R 2 and then R n and so on.

Here the ratio; let us start with the term it is L n plus 1 by L n. So, L n plus 1 will be somewhere here and L n will be somewhere here, you can see that L n will be larger than L n plus 1 and hence tau will be always smaller because this is small this is large. So, tau is generally small and we will see in a few minutes that this tau typically can be of the order of between 0.7 to about 0.95, we will see what are the affects of the value of the tau, but this tau ratio is constant for all the other dimension. So, for example, tau is equal to R n plus one divided by R n or this is also same as this spacing divided by this spacing. So, now, comes the next part how do we actually design these antennas we will see that how to do the design, but as you can see here that all the dimensions are varying by a ratio here.

Then comes the next point; why these are called as log periodic? There is a no log coming into picture here, well log will come into picture if you actually take log on this side here. So, what will be the log of this? This will be log tau log tau will be equal to log of L n plus 1 minus log L n so; that means, now log of L n plus 1 will be equal to this minus L n will go to this one that side will be then log tau plus log L n so; that means, every next length will increment by a value equal to log of tau and that is how the name log periodic name has come.

Similarly, you can say R n plus 1 log of R n plus 1 will be equal to log tau plus log R n, now here what is not mentioned here I will just mention that part which is the diameter. So, the diameter of these dipole antenna also should vary in the same fashion. So, you can say that the diameter of dipole antenna for this and this also should follow the same ratio; however, generally that is not possible let us say especially in the beginning people were using mostly these as a let us say aluminum tube. So, you cannot really have a let us say if they are the 10 elements then you need a 10 different diameters of aluminum tube. So, generally what is done, they actually divide this as a group. So, let us say if we take this entire array with divide it into 11 different groups. So, one side of the group will have a one diameter then in between group will have another diameter and this one will have another diameter and the choice of the diameter is given by if you recall again the dipole antenna.

The dipole antenna, we had mentioned that the diameter of the dipole antenna should be between lambda by 100 to lambda by 10 in the most extreme case. So, diameter does play an important role in the design of the log periodic antenna. So, now, from here we can define the angle you can actually see this is an angle alpha. So, half angle will be tan alpha by 2 will be given by tan alpha by 2 will be this distance which is nothing, but equal to L n by 2 because that is the L n th element and this will be divided by this part here which is R n or if we take for L n plus 1 then this will be R n plus 1. So, now, this is the ratio which is the known as the scaling factor this is the ratio angle which is width which is varying there is a one more parameter which is very important for defining the log periodic and that is the space factor sigma.

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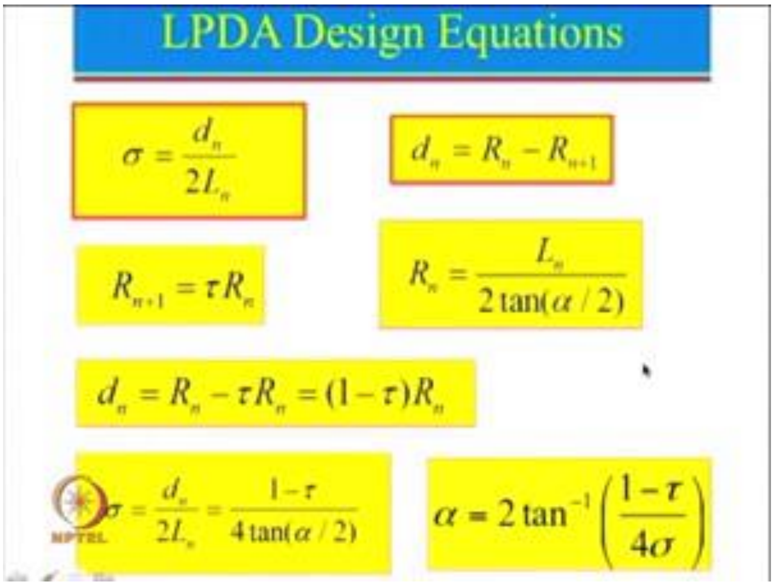

And I just want to mention this space factor is will take to the spacing between the element. So, you can see that the length of the dipole defines this particular dimension and this d n will define the dimension in this particular side. So, suppose these is a one element here then the next element will be given by d n then next element well be let us say d n plus 1 corresponding to L n plus 1. So, after that the derivation is relatively straight forward. So, we have defined d n equal to R n minus R n plus 1 and the tau ratio we know that R n plus 1 divided by R n was equal to tau it has been taken over this side and that R n is also rewritten in the form of the angle and now we simplify these things just by simplifying this I have given the step you can see that this is finally, reduced to this term over here and from here we can see if I take write this whole thing as tan alpha by 2 is given by 1 minus tau divided by 4 sigma so; that means, if we know sigma and tau, we can calculate alpha or alpha is known and if tau is known then we can find value of sigma. So, this actually thing will become the basis of the design of the dipole antenna and then log periodic dipole antenna.

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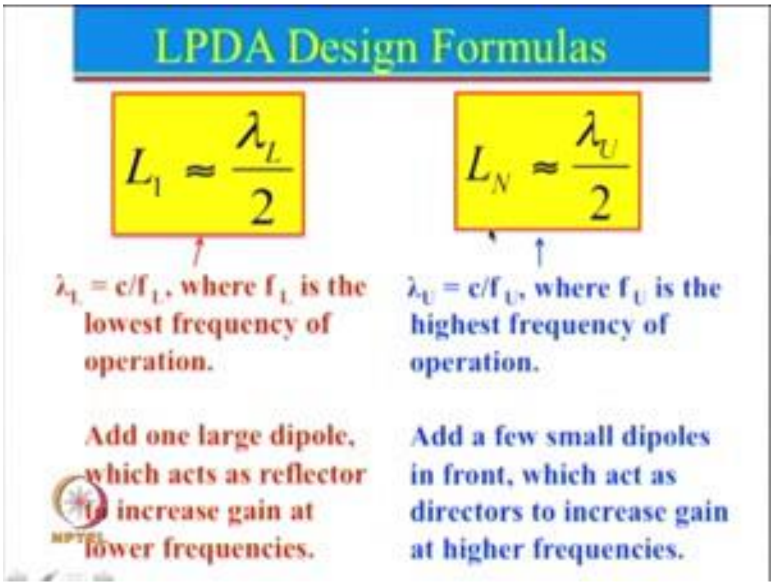

I will just give you the first step here and then we will continue from here in the next lecture. So, what is generally thing the starting point will be that we need to let us say design a log periodic dipole antenna from let us say f L to f U that is the lowest frequency and this is the highest frequency. So, we start with the lowest frequency choose the dipole length and then we start terminate to the highest frequency and find the length corresponding to that.

So, will continue from here in the next lecture, but I want that all of you please look at this derivation for the next lecture. So, that it will be easier to understand and we will take several design examples how to design a log periodic antenna from start to finish and will also take some practical examples and will also look at some simulated results also.

With that thank you very much and will see you next time.