Antennas
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Module - 11
Lecture – 50
Yagi-Uda and Log-Periodic Antennas-I

Welcome to today's lecture on Yagi-Uda and Log-Periodic antennas. In fact, today we are going to talk about Yagi and Uda antenna first, and then we will talk about log periodic antenna. Now you might wonder why I am talking Yagi-Uda and log periodic antennas together, as we will see later one that there are lot of similarities between Yagi-Uda and log periodic antenna and of course, there are lot of dissimilarities also. So, we will see what are the differences between the 2 different types of antenna.

But just one of the major difference between Yagi-Uda and log periodic antenna from the performance point of view is, that in Yagi-Uda antenna we try to optimize for higher gain whereas, for log periodic antenna we try to optimize for larger band width. So, we will just see now one by one, let us start the topic Yagi-Uda and log periodic antennas. So, we will first start with the Yagi-Uda antenna.

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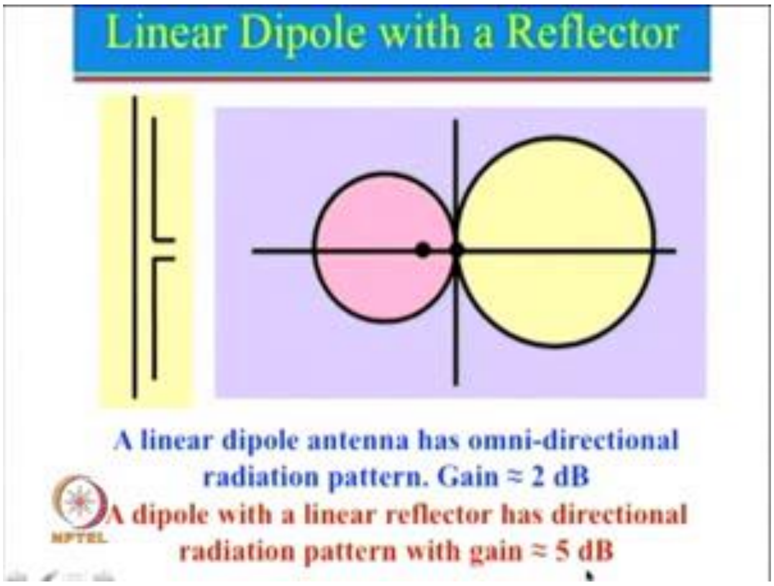

So, we will start first with the linear dipole with a reflector. So, what we really have here is a, you can see here there is a one dipole antenna and a reflector has been put behind the dipole antenna.

Now, we know that for a dipole antenna the radiation pattern is Omni directional; that means, it is Omni in this particular field; that means, H field is around this which is uniform, and E field is 0 in this direction and E field is maximum. So, E field actually is a like your figure of it goes here maximum comes to 0, then becomes maximum here and then goes back to 0. Now when put a reflector and there is a condition that dimension of the reflector must be larger than the dipole antenna. So, if this dimension is larger then what happens? This reflector will reflect a signal which is going towards this here.

So, the wave which is going to radiate from here sees a reflector deflects back, and radiates more in this particular direction. So, generally speaking when you put a reflector behind a dipole antenna, one can see that now there is a more radiation in this direction whereas, there is a less radiation in this particular direction because of the reflector which has to be lager then the ground plane. So, typically for a dipole antenna gain is around 2 dB, but a dipole with a reflector has approximate gain of 5 dB.

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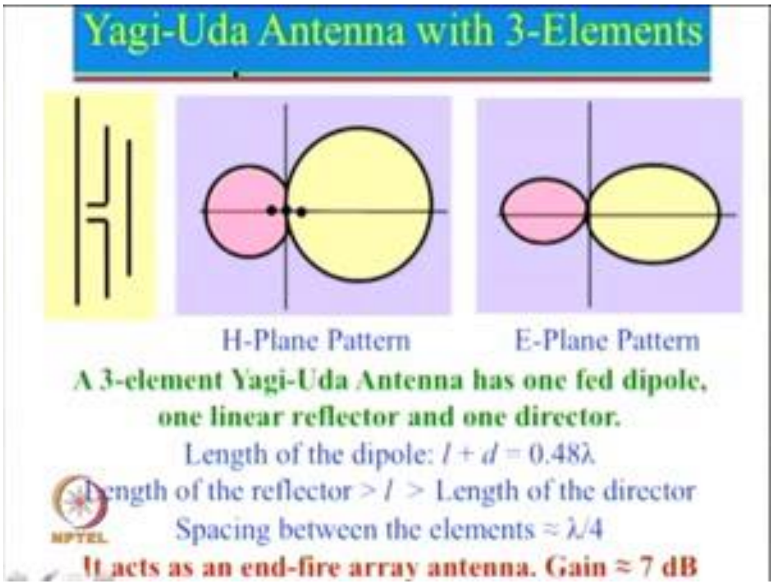

So, after this now we will talk about what is a Yagi-Uda antenna. So, Yagi-Uda antenna consists of this started with this that there is a one reflector here, then there is a fed dipole, and then there is a director. So, this director here has an important role here now the question is why the name Yagi Uda. In fact, these were 2 different Japanese author. In fact, Yagi proposed separately this concept, Uda proposed this concept also separately and then later on it actually became known as Yagi-Uda antenna just like in our music industry we have for example, Shankar Jaikishan, Laxmikanth Pyarelal similarly now there say Jodi in scientific community also which is Yagi-Uda antenna.

So, in this particular case now a Yagi-Uda antenna consists of this is a 3 element, we will see the general case also. So, there are 3 element Yagi antennas, which has a one fed dipole one reflector and one director. Now we know that length of the dipole should be given by l plus d equal to 0.48 lambda, if you choose this length then what we have seen then the input impedance of the dipole is real impedance, and if we satisfy this condition input impedance of this is approximately 68 ohm, and now we when we put the reflector as I have mentioned length of the reflector should be greater than length of the dipole and then length of the director.

Then comes the next part what should be the spacing between the elements. So, as a starting point let me must mentioned, and then we will see what are the rangers; typically this spacing should be about lambda by 4, and typically this spacing also should be of the order of lambda by 4. And if we do that then this whole combination acts as an end fire array. So, let us is look at the concept of y it act as an end fire array. So, you have to actually recall the array theory if you recall array theory, we talked about if there are 3 elements which are fed with let us say equal amplitude, but different phases then what happens? If the phases are different then the radiation can be in different direction for example, if all the 3 elements are fed with same phase, then it will radiate in the broad side direction; and if the phases are in different values then it may radiate in different direction and the phase condition can be obtained. So, if you want the radiation to be in the particular direction, which will be end fire array.

So, for that case we know that psi which is given by beta d cos pi plus delta. So, there cos pi is measured pi is measured from this access. So, pi should be equal to 0. So, cause pi will 0 means cause 0 means it will be 1. So, now, for maximum radiation psi also should be equal to 0, so this implies that delta should be equal to minus beta d; and if d which is the spacing is approximately lambda by 4, then what is the value of delta? So, delta will be now minus beta which is 2 pi by lambda. So, 2 pi by lambda multiplied by lambda by 4 which gives us a value of pi by 2. So, the phase difference between these elements should be equal to pi by 2 now how that is achieved?

Now, first of all now let us talk about the differences; in case of a linear end fire array all the 3 elements would be fed then one angle 0, one angle minus 90, one angle minus 180, but over here we are feeding only one element. So, this element when it radiates another element because it is in the close approximate when think about this here, this one will radiate like this, and that it is getting coupled to both this one here as well as the director. So, now, this length which we have chosen given by this particular expression that will give us real impedance, we can say that the phase will be something like one angle 0, if I assume one to be the distribution.

So, now this is excited. So, this field will both there; now this length is larger than this here and we know that if the length is larger than lambda by 2, in that particular case the impedance of this will be inductive and if the length is smaller than lambda by 2, then the impedance of this will capacitor. So, now, just think about this. So, this is inductive which will be let say angle 90 degree, then this will be angle 0 degree, this will be angle minus 90 degree. However, these things also have a resistive component. So, we are not feeding this antenna here, but because of the mutual coupling some impedance will be there. So, it was still be a largely capacitive impedance and largely inductive impedance, but still it will have some real value also.

So, because of the real value phase angle of this will be not precisely 90 degree, this will be also not precisely minus 90 degree, that is why we have written here this should be approximately lambda by 4. Some optimization is required to compensate for the fact that this is not really exactly one angle 90 degree and this is not exactly one angle 90 degree, but never the less if we have something like this here, we can get a gain of about 7 dB. Of course, theoretically maximum possible can be about 8 dB, because if this combination gives us about say 5 dB or so then additional you can say aperture may give maximum 8 dB, but our experience is generally you get about gain of approximately 7 dB. So, after this initial thing now let just see the general Yagi-Uda antenna array configuration.

So, general Yagi-Uda antenna consists of one reflector one fed element, and it can have number of directors. So, here the concept is if you have more number of directors gain will increase, but if you think about any organization more number of directors does not mean gain in the organization. So, sometimes these wires are better than the human being right just on the lighter science.

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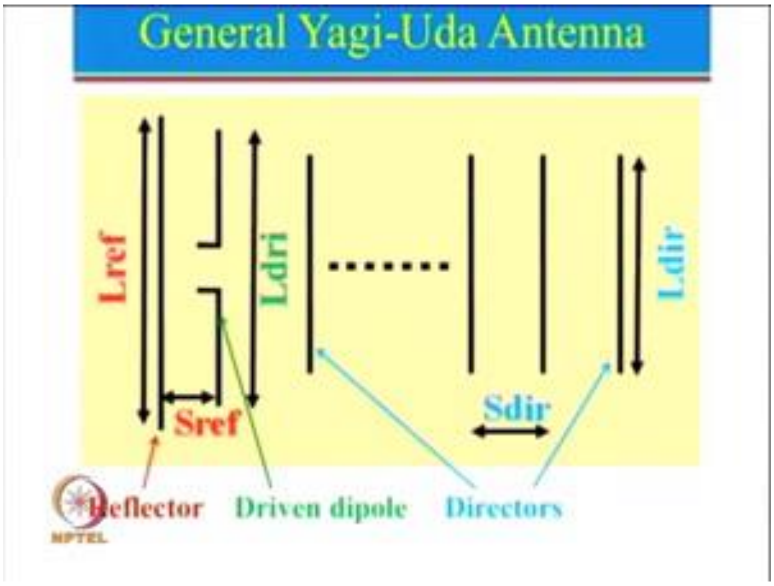

So, now let just look to the configuration here. So, here we have a fed dipole, and this one here is a reflector which is defined by the length which is l reflector here, this is the length of the you can say driven element that is y Ldri, and this is the spacing between the director which is Sdir and this is the length of the director.

Now, it is not necessary that all the elements in that director should be of equal length; however, for simplicity majority of the time people do take these lengths to be equal, but there are many cases where what they do? The generally take initially larger length of that director and then towards the end the length may be slightly less, but right now let us assume that these directors are of equal length and then the spacing. So, this is the spacing between the reflector and the fed element, and these are the spacing between the directors; and as I said in the simplified way all these spacings are taken equal. So, one can see that here we have a number of a directors, and the purpose of having number of directors is basically to increase the directivity. So, now, let us see what are the typical values of the different component.

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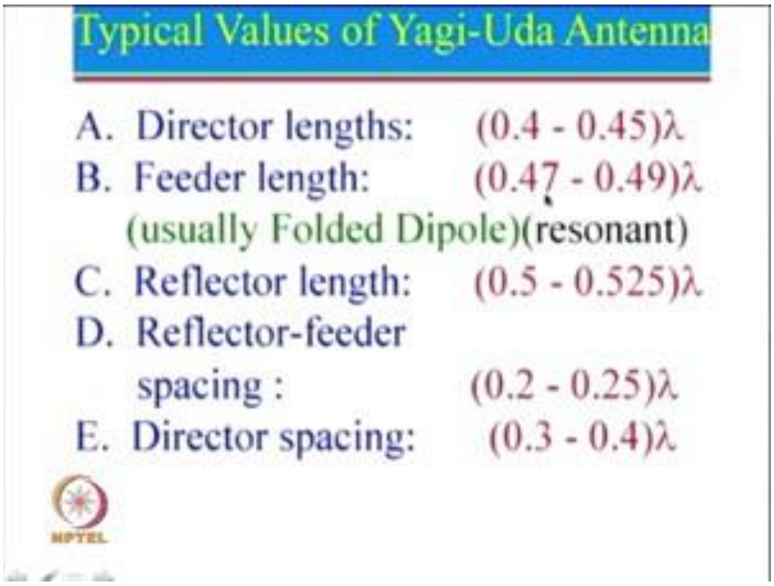

So, we will start with the feeder length. So, usually folder dipole, and just to tell you here these values have been taken from the (Refer Time: 11:17) book, I will tell you where I agree and where we do not agree 100 percent with these values. So, let us just look at these one by one. So, to start with the feeder length, now it shows here 0.47 to 0.49. I do not really agree with this value here, if you recall the previous expression I had said l plus d should be 0.48 lambda. So, if the diameter is 0.01 lambda, then feeder length should be about 0.47 lambda because that will be 0.48 lambda minus 0.01 which is 0.47.

So, this will generally not be there, most of the time you will see feeder length can be about 0.44 to about 0.48 lambda. So, small change here, and then the reflector length; reflector length must always be greater this here. So, suppose if you have chosen 0.47 you can choose about 0.5 here. So, generally reflector length should be larger, you can take a larger value. If you take a larger value of the reflector, there will be definitely an advantage where what we will see is that the back radiation is reduced. So, you can actually imagine about let us say think about the dipole antenna. So, let us say dipole antenna is here. So, this dipole antenna will have a radiation pattern E Plane pattern is like this right, and it will be same in this direction.

So, now, one can see does not radiate in this particular direction, maximum radiation is perpendicular to it. So, now, when I put a reflector behind this, so what will happen now? So, this is radiating maximum when this it will go reflect pack from the reflector, and now this field here is maxima it is reducing. So, even this part will get reflected, but now if you see this is actually also going to radiate slightly less here, slightly less here and almost close to 0 here. So, if I take a reflector length little larger, then there is a no harm if you take a little larger even this wave will get in reflected back.

So, you can take a larger reflector length and if you take a larger reflector length, what it will do? It will actually speaking reduce the front to back ratio, but many a times we have a space constraint also. So, that is why the recommendation is it must be greater than the dipole and if you can take little larger there is no harm, because your front to back ratio will only improve. So, let just look at the other dimensions now. So, you can see here if it 0.47 you take larger than that, but you can take a larger value if the space allows. Now fourth the director length typical director length can be 0.4 to 0.45 again I do not recommend 0.45. So, it can be from 0.4 to about 0.44 lambda.

So, small change over here and then comes the next part spacing. So, you can see here reflector spacing is around 0.25, but generally 0.2 to 0.25 is acceptable. Now here it is given that the director spacing can be 0.3 to 0 0.4, I generally do not recommend that. So, what I recommend is generally director spacing of may be 0.25 to 0.3, because instead of taking a larger spacing I do recommend that you can take more number of elements and by taking more number of elements you can actually enhance the gain. So, it is not necessary that what you read in the book, and also please remember when these books were written those there is we did not have the power of computers. Now a day’s lot of computation can be done, lot of things can be changed, and optimization can be done hence we start with the initially guess and then we do the optimization.

So, here is the next one now. So, what is the advantage of the having more number of directors?

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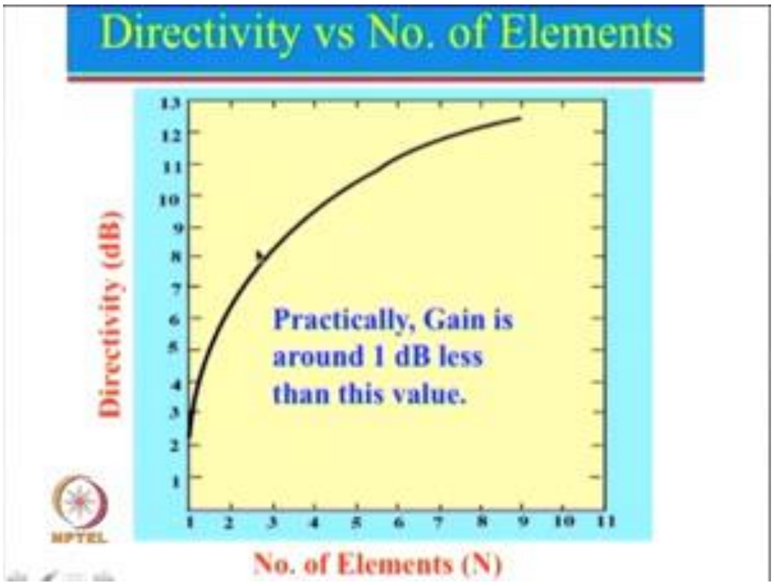

So, let us see the curve here. So, this is the directivity curve versus number of elements. So, again I would like to mention one thing. So, even though this is given in the books here, but generally consider this as directivity, but I do not agree with this curve, you generally would not get this value, you can probably optimize may be you can try to get the limited value of this. But generally my experience has been that practically gain is around 1 dB less than this value. So, this is the good starting point. So, for example, let say if you have 3 elements this is the number of total element. So, if you go up here 3 element is somewhere like this, you can see that it shows about 8 dB gain.

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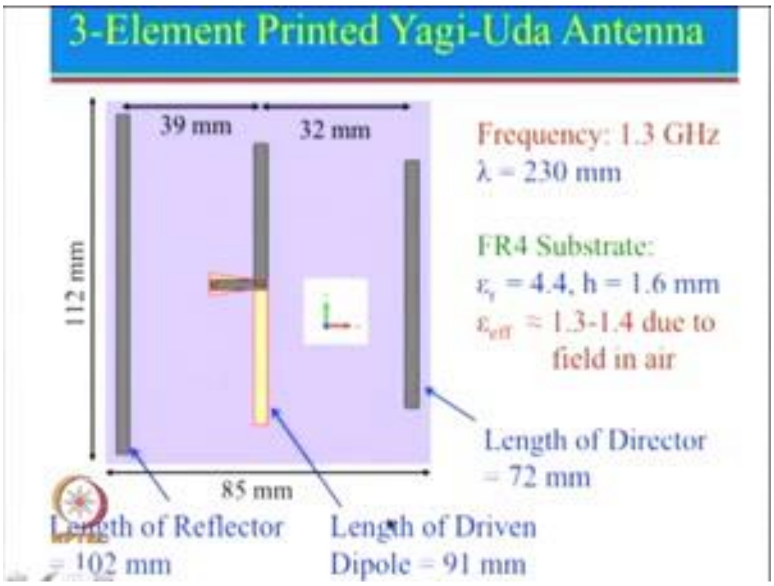

But we will see that practically you get generally about 7 dB gain or. So, so will see some of these cases one by one, and now let just see how to realize these antenna. So, here is an example this example is of a 3 element printed Yagi-Uda antenna. So, we are not using the wires. In fact, majority of the time earlier Yagi-Uda antennas actually use the typically here they had use the aluminum; rod aluminum rod so over here, aluminum rods here and then they will provide the support over here. And generally in the earlier design they had used the balun over here, balun is what balance to unbalance. So, coaxial feed is there. So, at coaxial feed will be then connected to balun, and that balun will give provide the balanced feed. Over here we have use the little different concept; here balun has been replaced by a micro strip to equal to and opposite current values here.

So, you can actually see over here, this is basically a substrate and we have chosen a low cost FR4 substrate, and I will tell you the pros and cons that also. So, for this substrate epsilon r is 4.4, h is 1.6 mm that disadvantage of this substrate is the tan delta is of the order of 0.02; advantage of this is that it has a low cost. Now let us just come back over here. So, what we have that this is the driven dipole, and this is the reflector and this is the director and one what you can see over here? These dark grey colors basically are on the front side of the substrate and this is one the back side of the substrate. If you recall when I was talking about dipole antenna, I had a mentioned about this particular configuration, but since it has been a long time when we cover dipole antenna I just quickly go through it.

So, what we really have here? This portion here is printed on the back side, and the top you can see over here. So, the connecter is connected from the back side let us say SMA connector and the SMA connector ground is solder to this part here, and the SMA connecter central pro feed point is soldered over here and then; that means, this will be unbalanced point, and from here it is tapered. So, over here the width of the line will be same as the width of this particular line. So, this transition basically acts as a balun. So, from unbalance we are getting a balance. So, here since these are in the opposite direction, it provides plus and it provides minus here. So, that is our effective you can say dipole antenna very simple feed technique, and here is a reflector and director.

Then comes the next part; so we have designed this antenna at 1.3 gigahertz; so the wave length at that value will be lambda will be 23 mm which is nothing, but c divided by f. Now even though we have chosen epsilon r 4.4, but effective dielectric constraint is much smaller; unlike if you recall micro strip antenna if epsilon r was 4.4, effective dielectric constraint was close to 4r, but over here it is much less than that. The reason for that is there is a no ground plane in the back side of this here. So, basically this is the only part which is the dielectric material rest is all air. So, think about again a dipole antenna. So, the dipole antenna will actually radiate in the Omani direction; so if since the dipole is like this here, it is going to radiate like this.

So, only this particular part is confined within the dielectric material, this one is entire air this one is also air. So, the field which is like this here that field only the little part of that filed is confined within the dielectric material. So, that is why epsilon r effective is of the order of 1.3, 1.4; and I want to mention here is insert of 1.6 mm there are substrates which have 0.8 mm thickness. So, if you take 0.8 mm thickness then this epsilon effective will be of the order of approximately 1.2, and if you take even thinner substrate then epsilon r effective can tend towards one. So, because of that here when you want to do the design. So, we know that this particular dipole length should be given by let say l plus d equal to 0.48 lambda.

But now here lambda is not free space lambda. So, lambda here will be now 230 which is free space lambda, divided by epsilon effective; and that is how the length has been calculated. And you can see the reflector length is larger than this, and the director length is smaller than this. I want to emphasis here this is not the optimum antenna, one can still do optimization. In fact, this antenna I had designed it more than 15 years back and we had done the transfer technology, because we had created a set for antenna trainer system. So, it is more for the educational purpose not really the optimum Yagi-Uda antenna. So, let us see what are the simulated and measure results for this particular case.

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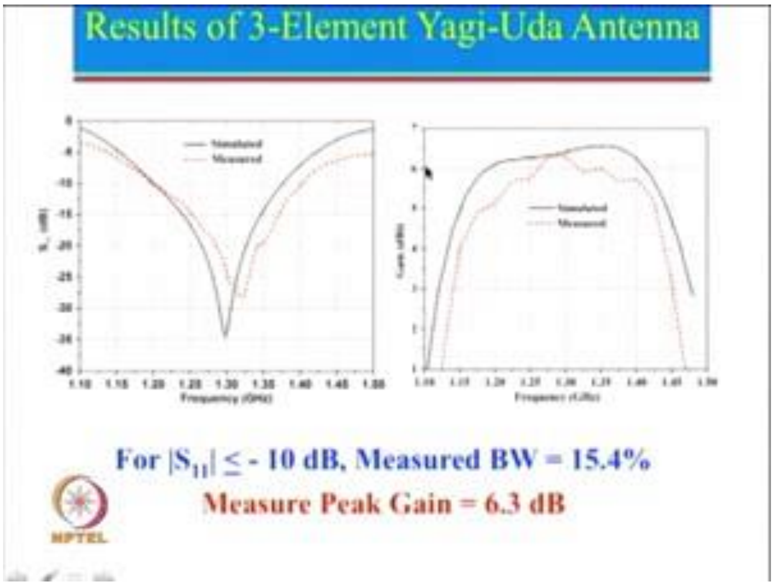

So, here is the simulated and the measured S11. So, one can see that this is the measured simulated result it was designed at 1.3 gigahertz, the measured result is slightly off over here; however, if you look at the S11 less than minus 10 dB, which is approximately w s w r 2; so, if you draw the line over here, and calculate the percentage band width. So, the measured band width is approximately 15 percent. Now let us just look at the gain plot. So, this is the simulated gain plot, you can actually see that this is about 6 dB, it is actually less than 7 Db, and these are the measured plot. So, now, you might wonder that gain is not even 7 dB, when I had shown that I had said that the gain can be approximately 7 dB.

In fact, when I mentioned about the gain equal to 7 dB that was the situation when these dipole antennas are in the free space, in the free space there is a no dielectric medium; now over here now all the patches are printed on the substrate, and this is your lossy substrate; and the wave is propagating along this direction. So, since the wave is propagating along this direction part of the wave is propagating through the dielectric medium and here it is a lossy dielectric medium, and that is why the gain is reduced. So, if you take a better quality substrate for example, there are substrates which have a tan delta equal to 0.001, instead of this affair force substrate which has a tan delta of 0.02 you can get an advantage of approximately 0.5 dB.

So, yes you are losing a gain of about 0.5 dB, but FR4 substrate cause is approximately 30 times less than the expensive substrate. So, you have to decide whether you want to pay more money and get little better gain or pay less money, and how a slight reduction in the gain it is not a major reduction, but there is a small reduction. So, you have to see performance versus price.

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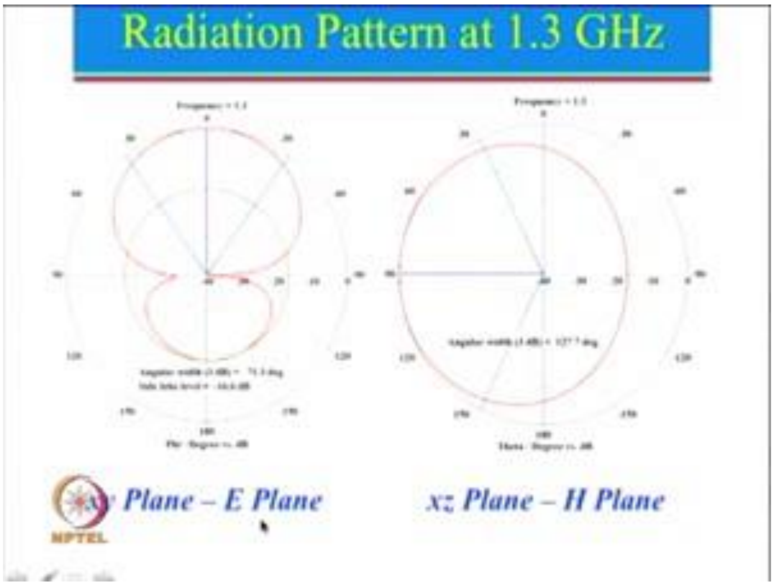

So, now let see the radiation pattern. So, here is the radiation pattern E Plane pattern and H Plane pattern. Now many a times when you do this simulation you will actually see x y plane, and you see here x z plane. So, it is important to understand what are these x y plane and y in x y plane we have a E Plane.

So, let us just remember x y plane and x z and we will see the figure. You can see here it is actually shown here this is x y. So, x y plane if you look at that is the plane of; you can say substrate. So, in this particular plane you can see that E field will be there, E field is what in this plane? Field will be 0 in this direction and it will be a maximum and going to 0 here. So, this is the E Plane and what is the x z plane? X is this; z will be perpendicular to that. So, that will so x is in this one z is this. So that means, this is now going to be our H Plane. So, that is how you have to see. So, many software give you different kind of a thing for example, this one was simulated using CST microwaves studio. So, they generally defined as x y or x z plane; where as if you look at I 3 d most of the time they will write e theta and 5 equal to 0, or 5 equal to10, or 5 equal to 90 degree plane.

And that e pi n pi equal to 0 or 90 degree plane. So, you must understand the normal cloture, but basically if you have understood that if this is the dipole antenna is like this. So, H Plane will be in this particular fashion, and that is what is the x z plane. So, you can correlate quickly, and then E field is in this plane which is nothing, but x y plane. So, that is how you can say this is a E Plane pattern. So, that is let us just look into the pattern then. So, you can see that E Plane pattern is relatively in r over compare to the H Plane pattern. So, you can actually see here and that is expected because in E Plane pattern it is a directional pattern more likely a dipole direction, and that is why array factor has to be applied to this whole thing. So, this one is actually speaking acting like a E Plane relatively narrow, this is the front radiation this is the back radiation.

And over here you can see a H Plane. So, you can see that there is much wider beam width over here compared to this; because this one H Plane correspond to that how many pattern to the how many pattern we are multiplying the array factor. And over here it is a directional pattern, which is getting multiplied by the array factor; and that is why the beam is relatively narrow r over here compared to them. So, we will conclude today's lecture at this particular point; so for what we have discussed we have actually seen that we start with the let say dipole antenna, then behind the dipole antenna you put a reflector. So, combination will give us about 5 Db, and then we keep adding directors if you have just add to one director then will get approximately 7 dB gain. So, that is for element then after 3 elements, if you add in other 3 element; that means, aperture is increase by 2 times.

So, instead of 7dB you can get about 10 dB or so. So, that is how by adding more number of elements you can actually increase the directivity or the gain of the Yagi-Uda antenna. And the band width of Yagi-Uda antenna depends upon the band width of the dipole antenna. So, if you take a larger antenna you will get a little larger band width; however, band width gets limited because of the reflector and the director position. And we also look at the very simple feed network where we had use the coaxial feed, and that coaxial feed actually was connected to the ground part and the top part was connected to the top of the substrate, and then half of the line went up there other half went down there, and those two were at the opposite pacer.

In the next lecture now we will see some of the recent developments where people have used the Yagi-Uda antenna for different concept; by using the different concept they are able to increase the band width of the Yagi-Uda antenna, and also we will looked at the different ways of feeding the Yagi-Uda antenna.

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