Antennas
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Module – 12
Lecture – 57
Reflector Antennas-II

Hello and welcome back to today's lecture on Reflector Antenna. In the previous lecture we had started talking about reflector antenna. So, in the last lecture we had started talking about reflector antenna and we looked into simple concept of the planar reflector, then we talked about corner reflector, very briefly we talked about curved reflector.

And then for the planar reflector we actually started with the horizontal dipole antenna over infinite ground plane, then we talked about to vertical dipole antenna over a infinite ground plane, and then we talked about the horizontal dipole over a infinite ground plane. And then we just looked at the concept of the corner reflector and we also saw that a 90 degree corner is a very nice reflector, specially because it reflects the signal exactly in the same direction. So, let us continue from here.

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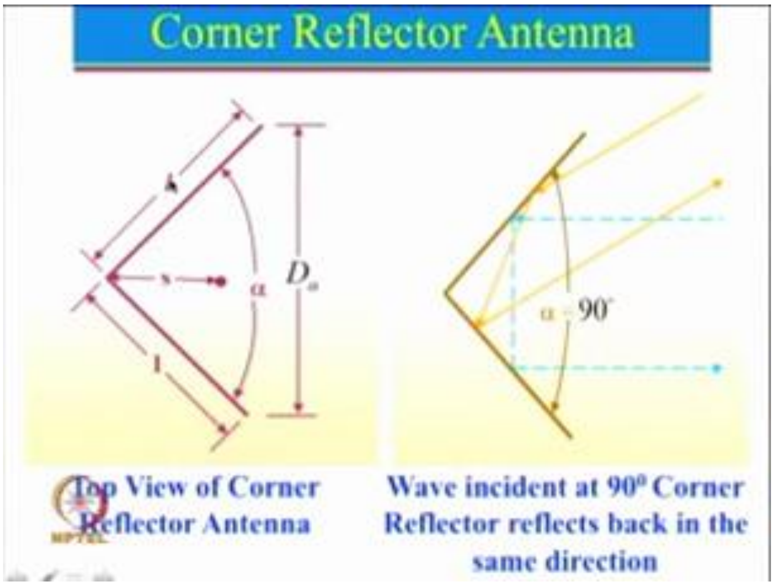

So, we had actually started the discussion on corner reflector antenna, so this is a corner reflector antenna of length l and height h, and in the beginning we will assume l is infinity and even the height of the reflector is infinite. This was the concept which we had looked at when we have a angle alpha equal to 90 degree, any incoming wave reflects back in the same direction.

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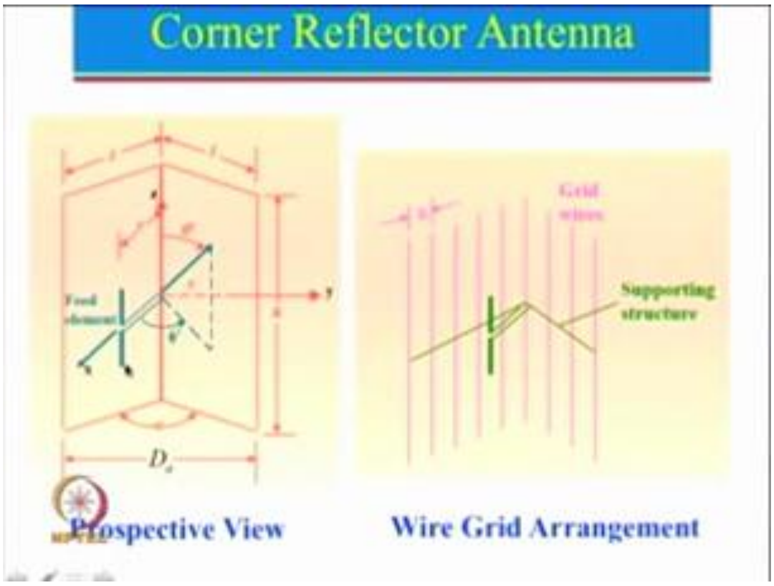

So now let just look at the corner reflector; so this is the perspective view or you can say that the 3D view. So, here is a reflecting plate: so one plate is here another plate is here, then length of the reflecting plate is l and the height of the reflector is h. And here you can see that this is a dipole antenna, and one can see that this dipole antenna has to be supported somewhere it cannot stand on its own and the free. So, some supporting is structure is provided over here and through this supporting structure which can be for example of plastic pipe or an dielectric pipe and through the dielectric pipe a feed can go here plus and minus feed over here.

And over here a few important things: so this is the angle alpha. And the most important thing in this particular case is also that this spacing; spacing from the corner of the reflector to this particular dipole. As we will see later on this spacing is extremely important and it governs the gain of the pattern as well as the radiation pattern of the reflector antenna.

So, with this simple concept sometimes we actually use this here which is known as a wire grid arrangement. The reason for that is if we use these large metallic plates, think about the wind loading. Let us say if it is installed on a roof top then there will be a lot of wind loading will happen and if the dipole is of a vertical thing which has a vertical polarization then this entire plates can be replaced by vertical wires. Now there are certain conditions are there: the spacing between these wire can be between 0.1 lambda to 0.25 lambda.

In no case in this spacing should be lambda by 2 or greater than lambda by 2, because if suppose this spacing is equal to lambda by 2 then lambda by 2 this is a short there will be a maxima and it will be minima here; so 0 maxima is 0. So, boundary condition will get satisfied and all the radiation will go through this particular gap to the back side. And in fact what we want is; no radiation in the back side of the reflector.

So, generally speaking the condition is this spacing should be between 0.1 lambda to about 0.25 lambda. And there is really not much of it needs to take distance less than 0.1 lambda. Of course, these vertical things will not stand on its own, so you need to provide some connecting configuration over here or a structure. So, that it can stand on its own. So, rest of that you can see here there is a supporting structure and there is a supporting structure for the dipole antenna also.

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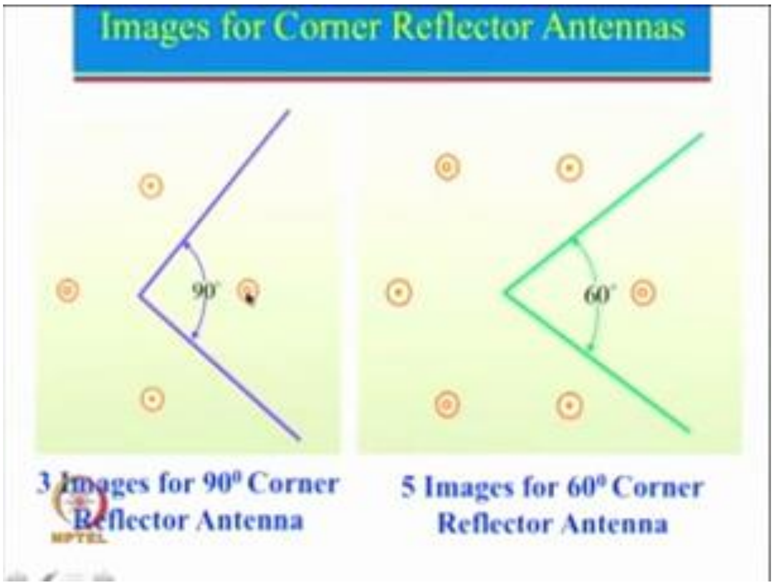

Now let just see what really happens. Again we will start with the 90 degree, but this time it is a reflector antenna. Why antenna? Now we have put a feed over here. So, here again this is the top view. So, if you see from the top view you will only see the tip of the dipole antenna. So, that is what is shown over here. In fact this is actually shown as a arrow. So, if you have an arrow what to do we normally represent arrow as? The tip of the arrow is represented by a point, and the back of the arrow is generally represented by a cross like this here. So, let us see what we are representing over here?

So, assume that this is not the reflector and we also assume that this is a infinite dimension over here. So, if you have a plain reflector like this, then if this is in this particular going up here then this image will going in the back side. It like just like for this particular case where it is like acting like a horizontal dipole to this particular plate. So, for horizontal dipole we had seen image will be in the opposite direction, just like I had explained that if you stand in front of the mirror a right hand looks like left hand and left hand looks like right hand.

This is the way it has been represented. So, if you look at the dot here that dot will become cross. So, from here image is formed and this distance will be exactly same as so this distance is equal to this distance here. Then the same thing will happen for this side also. So, from here image will be formed and if this is dot this will be cross. So, these two images easy to understand; why these two images are coming.

What about this particular image here? To understand this one I actually think that you imagine now these reflector are extended to infinity. So, this one goes over here and this one goes over here. In fact, the parallel of this to explain and understand recall if you go to let us say a barber shop and many of times you will see in the barber shop there is a one mirror in the front side and there is a one mirror in the back side, and if you see through the mirror you will actually see almost multiple images theoretically number of images will be infinite.

Why that happens, because let us say a mirror is in front of you so there will be a image, but then there is a mirror at the backside of you so that will be a image. Now for that image this mirror sees there is another image over there, it creates a image behind that. And for this image behind at the back mirror sees another image, so it shows over there. So, theoretically you can see a infinite images. But of course, here for 90 degree angle you do not see infinite images, but you can imagine that these reflectors are extended towards infinity as far as the image is concerned. And if you use this concept you will be able to fill up images for any other angle also. So, let us see one more time.

So, you can see that for this dot there is a cross and for this dot there is a cross, now you imagine this is extended like this and this one is extended like this. If it is extended like this here then what will happen this cross will see an image and the cross image will be now dot. And in fact, if you extend this whole thing like this here then this dot will see an image of cross over here. And that is how you can see that there will be total three images will be there for 90 degree corner reflector.

Let us see what happens for 60 degree corner reflector. Now, for 60 degree again let us start with the concept here this is the dot at the equal and opposite distance from this side there will be a cross, and then for this image 0 there will be cross. Now you extend this whole thing like this and you extend this whole thing like this over here. And if you extend over like this here this cross will have an image which will be dot. And if you extend like this here this cross will have an image of dot here.

So, one can complete that; now comes the last part. If we extend this over here then dot will have a image of cross here and if we extend like this, this dot will have a image over here which is cross. So, for 60 degree will have total five number of images.

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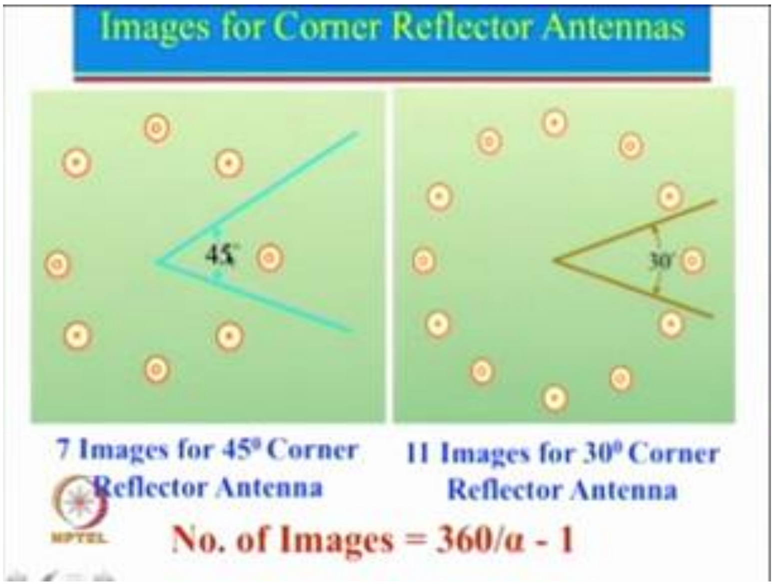

Let us see now what happens if we reduce the angle further. Here is the case of 45 degree, so one can again do the same thing this dot will be a cross here, dot will be cross here, now you need to extend this and you need to extend this over here. And if you do that for this cross you can see there will be image like this which will be dot, you extend this here for this dot, you can see that you know keep on repeating it you will see that the images have been filled accordingly.

So, there will be total 7 images for 45 degree. The same concept you can extend, so if this is 30 degree now number of images will be large. In general number of images you can calculate by using a very simple formula of 360 divided by alpha minus 1. So, we can just put it over here, so alpha is 30. So, 360 by 30 will be 12; 12 minus 1. If alpha is 45 degree 360 by 45 will be 8 minus 1. So, there will be seven images here.

Now, what really happens, so why do we keep on reducing the angle? So, you actually you conceptually you can think about that if the angle is let us say large angle, so what will happen when the radiation takes place let us say we have a dipole in between which is going to radiate. And now if the angle is this much here radiation will take place in that particular beam, but if I now keep on reducing this angle. So, if the angle is reduced so radiation can only be confined in this particular narrow region. And if the band width is reduced; that means gain can be increase.

So, theoretically you can reduce the angle to even 1 degree also, the practically nobody does that. But generally speaking 30 degree, 45 degree, 60 degree and so on are commonly used to realize a larger gain antenna. Of course, we took only example of dipole antenna, but one can use different antennas. So what will happen? Pattern multiplication will take place. So, if we have a gain of the antenna itself larger than the overall gain will be larger which will include the effect of element pattern as well as the reflection because of the different angle of the reflector.

Now, let see the variation of this how these can calculate the radiation pattern.

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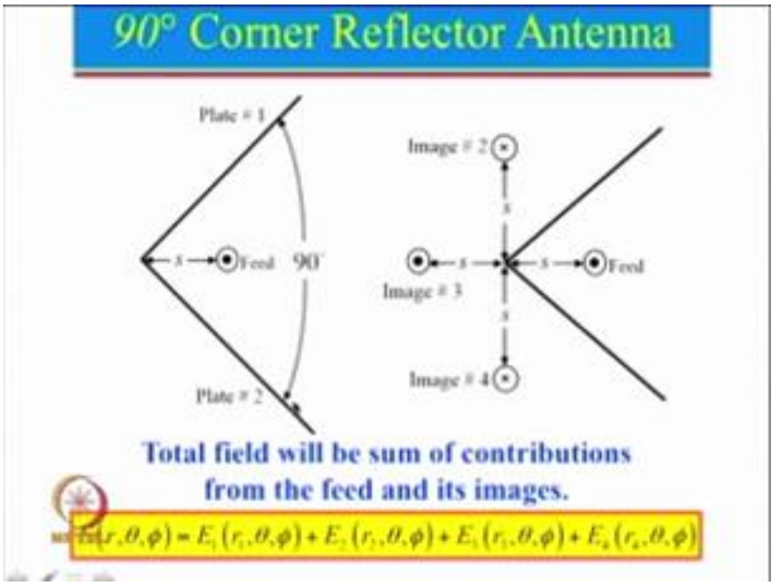

So, we will start with an example of 90 degree corner reflector. So, we have a plate 1, we have a plate 2, and here is a feed, you can see here there is a 90 degree angle here. Now, for this case we are seen that there are three images, so even though there are three images we are numbered them as number 2 3 4. The only reason is that feed has been given as a number 1, so there will 1 2 3 4 element. Now, we want to find out the overall radiation pattern. So, the total field will be nothing but the some of the contribution from the main feed as well as the images.

So, we can say that the overall feed will be nothing but summation of these field and these will be the vector some of these particular feed over here. Now we need to apply the array theory. So, if you recall when we discuss about the array. So, here what we will do? We will just assume that this is isotropic element just for our derivation. So, for a isotropic element we can find out the array factor and then subsequently one can multiply that with the element pattern. Now, when we want to find out the array factor you can actually think about that there is one element here there is another element. So, and the distance between the two element will be now S plus S which is 2 S.

So, for this particular case here we have seen that the array factor theory what is that; for n number of elements we know that the array factor will be sin n psi by 2 divided by 2 sin by psi by 2. Here n is equal to 2, so that will be now sin 2 psi by 2 divided by 2 sin psi by 2 and that gets cancelled and it becomes cos psi by 2. So, for these two things the pattern will be cos psi by 2. Now for these two again the distance is same S and S, but only thing is this is let say if it is in the x axis this is along y axis. So, the radiation pattern should account for x axis as well as y axis.

But again here you can see that these two are in the same phase. These two phases are different if this is a plus 1, this will be now minus 1 minus 1, but otherwise these two are in the same phase hence they will also give rise to the cos sin pattern. So, let just look at the pattern.

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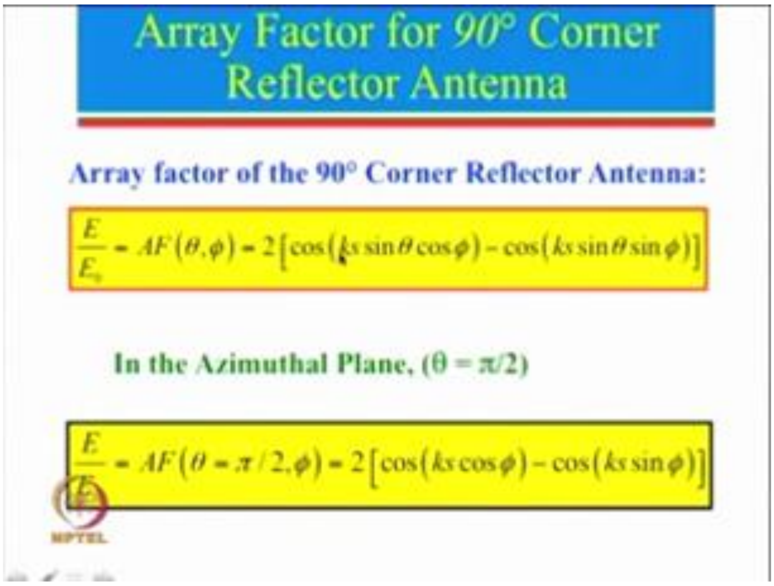

So, the array factor of the 90 degree corner reflector antenna will be 2 times, this is now cos. This term corresponds to sin theta cos phi, I will just explain we will go back to the previous line. But just you can see here, so this is equivalent to cos psi and this is again equivalent to cos psi, this is cos psi x and this is cos psi y. You have to think about planar microstrip antenna array; when we talked about the planar microstrip antenna we are introduce the concept of the sin theta cos phi.

So, what you have to think about here is? Let us say we have an element here we have looking at this particular point. So, if the array point is along the x axis. So, what happen? So, we take the projection, projection will be along the theta. So, always every time theta is measured from the elevation. So, whatever is this point here that will be theta projection of that in the horizontal will be equal to sin theta. So, you can see that sin theta term is represent for both the elements which are in the x or y. However, along the x axis what we need to do for any faraway point it will be multiplied by cos phi and for anything along the y axis it will be multiplied by sin phi.

So, you can actually see that these are the terms shown over here. So, for the elements along the x axis sin theta is common to both because it in the x y plane, and since this is the term along the x axis the term cos phi comes and this is the term along y axis with sin phi terms. So, the array factor of the 90 degree corner reflector antenna then can be written as 2 times cos psi x minus cos psi y. So, psi x term will have cos phi and along the y axis the term will be sin phi.

So, in the Azimuthal plane where theta is phi by 2 or you can say 90 degree, so if you substitute the value of theta equal to pi by 2 sin pi by 2 will be equal to 1 hence theta goes out. So, this is the radiation pattern or you can say array factor for isotropic element of two elements; that this is the array factor for a 90 degree corner reflector antenna for isotropic element, and this has to be multiplied by the radiation pattern of the antenna.

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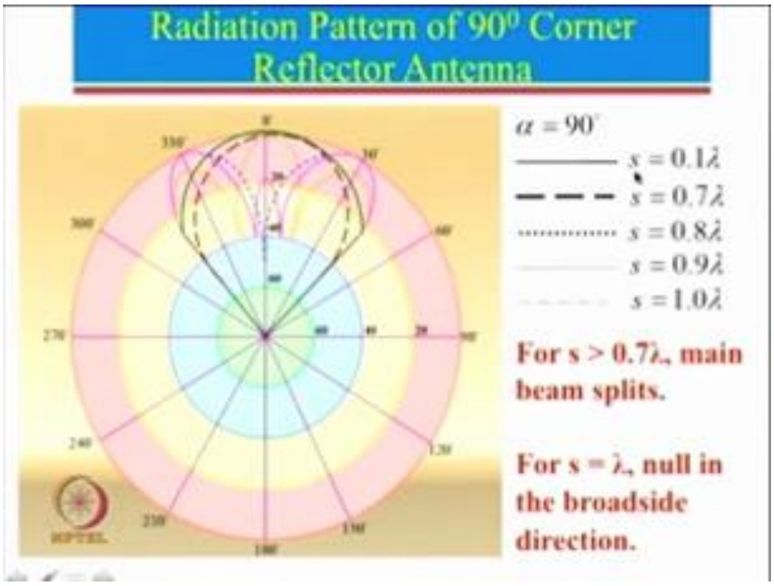

Now let just see the plot of this particular thing for different values of S. As I mentioned S place a very very important role, what is S? S is the distance of the dipole antenna from the corner of the reflector antenna. And again repeatedly I am saying dipole antenna, but in a reality it can be any other antenna.

So here, in fact let us just look into here. And in fact, in general the plot which I am showing you that is actually for isotropic element in general. So, let us say now if S is equal to 0.1 lambda; that means it is very close to the corner. So, for that particular case let us see this is the solid line. So, this is the plot over here.

You can see that there is a no back radiation over here, the reason for that is in this entire derivation it has been assumed that this particular length is extended towards infinity; we know that practically that will not happen. So, now, let us see what happens. So, 0.1 lambda is increased to let us say 0.7 lambda you can see dash dash dash. So, this is the plot for that.

You can actually see that this is still in the broad side direction, and you can also notice that the half power beam width of this is relatively less than the than the half power beam width of this. That means, for this case we get a higher gain. Now we increase it further then what we can see that now for this particular case you can see that there is a beam split has taken place. And if you go down to this case here S equal to one lambda in that particular case you can see that actually there is a null in the broad side direction. in general one should consecrate only in this particular region. So, I have actually summarise this for S greater than 0.7 lambda, main beam splits and generally that is not very desirable, for S equal to lambda there is a null in the broad side direction which is this particular point and that is also not generally desirable. So, in general one can think about you can choose the value between 0.1 to 0 0.7.

However, my recommendation is that please do not take S equal to 0.7 lambda also, in general try to restrict the value of S to about half of this here. So, why do I say that? The reason why I am saying is that all of these things assume that there is a infinite ground plane. But in reality there will never ever be infinite ground plane, we are always going to take a finite ground plane. So, let us just look at the back slide of the 3D view over here.

So, in the derivation it has been assumed that l should be infinity and this h should be infinity, practically we cannot do that. So, let me give you some practical cases here. So, we know that a dipole antenna will have the length of lambda by 2. Now this dipole will radiate nothing in this particular direction and it will radiate maximum in this direction.

So, you can see that the radiation pattern of this will be 0 here; it will make a figure of eight like this. So, you can see that this part is maximally radiated in this direction it will reflect back, but this one angle here you can see it is radiating little. In general I can tell you that if you take h equal to approximately equal to lambda it is fairly good enough, you need not take 2 lambda or 3 lambda or 4 lambda, because the gain is not going to be significant; so h equal to 1 lambda decent enough.

Now, comes that next part what should be this l. So, I can give you one simple thumb rule that this l should always be greater than or equal to 2 times S value. Suppose if you take S equal to 0.7 lambda then this should be 1.4 lambda that this is the minimum value. But if you take let us say S equal to 0.5 then this can be approximately lambda. So, that is why I said in general don t try to take 0.7, because that unnecessarily increases the size of the antenna, and there is a not significant gain. I will just look back to this particular plot here again.

In general just to tell you here, so the plot which you see here this is for 0.1 and this is for 0.7, in fact for 0.5 if you look at even though it is not there you can imagine that it is actually very very close to 0.7. So, the increase in the gain is hardly has significant value if you take it 0 0.5 or 0.7, but this 0.5 or 0.7 will make the reflector size instead of let us say for 0.7 it will be 1.4, if I take this 0.5 then the reflector length will be equal to lambda. So, one can save the size without really speaking any significant decrease in the gain, so we do not recommend anything more than 0.5 lambda for this particular case.

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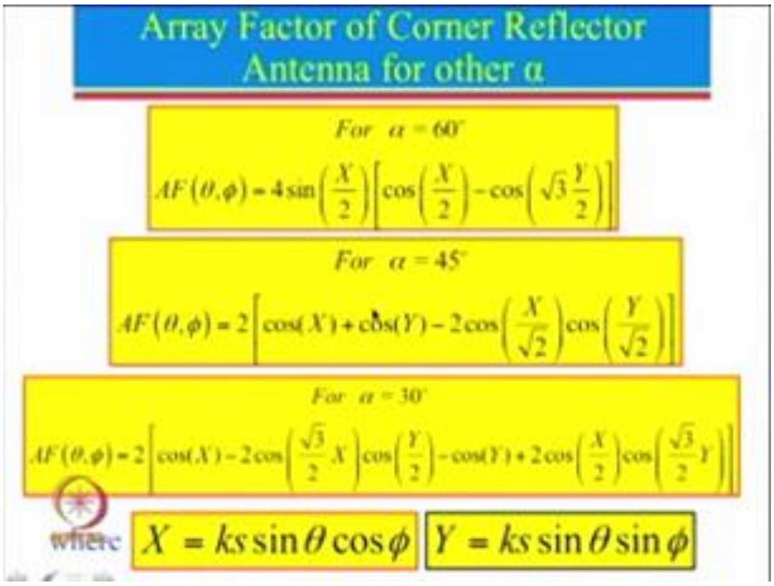

Similarly we can find out the radiation pattern of the various other corner reflector antenna for different values of alpha. I will actually start with alpha equal to 30 degree it is like a bottoms up approach. Here if you see alpha equal to 30 degree just recall the total number of elements including images were equal to 12. So, there should be total 12 terms because the feed is going to sum of all the term. So, let us say we have a 2; that means within the bracket total number of terms should be equivalent to 6. So, cos x will give rise to 1, then this term here 2 multiplied by with will give rise to maximum value of 2.

And over here again there is a one term, so that is another one and this one here is another 2. So, one can say 1 2 3 plus 1 4; 4 plus 2 6; 6 multiplied by 2; so that will be the total number of elements which is coming into picture. And x here is as before it is equivalent to sin theta cos phi and y will be sin theta sin phi, because it is in the y plane. So, theta remains same because it is x y theta will be constant and for elements along x axis we take cos phi and elements along y axis we take sin phi. Now for this is for alpha 30 degree.

Now, let us go to alpha 45 degree: total numbers of images including the feed are eight. That means, the total number of terms also should be eight. So, there is a two here, so inside the bracket should be 4. So, you can see 1 plus 1 2 and this is equivalent to 2; so 2 plus 2 4; so 4 into 2 8.

Now if you look at over here it looks little confusing, because 4 is outside and then there is a one term here and another term here, so its look like 1 and 2 2 terms multiplied by 4 it looks like 8, but that is not really the case; and I will tell you what it is. So, in this case if you open up this whole thing this term will be then 4 sin x by 2 cos x by 2 minus 4 sin this term multiplied by this.

Now four sin x by 2 cos x by 2 is actually equal to 2 sin x cos y, so that particular term really leads to a number two and this term here leads to four that is our total number is actually to 6 which is corresponding to 60 degree here.

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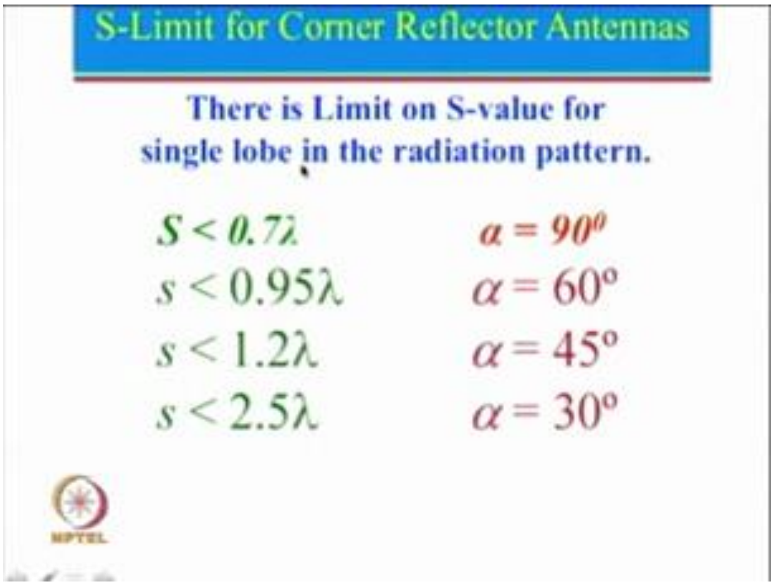

So now let us see; what are the S limits for different angle. So we saw that the limit for the S is up to the value where single lobe is there in the radiation pattern. That means, if we increase the value of S beyond this then there will be split in the main beam which is generally not desirable. So, what we really want is let us say for example, 0.7 is the limit for alpha 90 degree. So, if alpha is reduced to 60, 45, 30 you can see that this limit is 0.7 can become 0.95, 1.2 or 2.5.

However, again I do not recommend at all, please do not have any design which has a larger S value. In general just to tell you why we take a larger S value; generally speaking one takes larger value of S, so that gain will be large. But however, if you take a larger value of S then the reflector size has to be much larger. As I said general rule of thumb is l must be greater than 2 times S, if l has to be greater than two ways you take a larger as; that means the total aperture size increases significantly.

So, what we recommend is that you take the values of maximum is whatever is given by here I do not recommend you take more than half of this here. But let us see here why larger as gives rise to the larger gain. Think about this; if this value is large that means all these elements will be now will occupy a larger aperture, but if S is small then suppose if this is over here my total aperture will be reduce over here. So, you can see that my aperture size has increase hence gain will increase. But for larger value of yes you really then need a very large reflector.

And what we have seen that if you reduce from S here to here; that means reflector length can decrease significantly, but decrease in the gain is relatively marginal.

So, hence you please look into these things, and also I want to tell you one another interesting thing over here; for all these cases very little a literature is available for the finite ground plane. So, it is a very good research topic, most of these derivations are done when the corner reflectors are takes as infinite plane, whereas what I would strongly encourage any one of you since we have lot of good softwares which are available these days which would not available several decades back. So, what you can do systematically, you can study what is the effect of the finite length and then you come out with the simple solution what should be the limit on the value of S, and how much gain sacrifice will happen if you reduce the value of the S. As I mentioned gain scarifies is will not be significant, but the reflector length can be reduced at least by 50 percent.

So, with that I will stop at this particular point. Just to summarise that we have talked about the corner reflector antenna, we talked about 90 degree, 60 degree, 45 degree, 30 degree; we looked into the number of images and saw that how images can be formed. And then we found out what is the array factor. And once we know the array factor you can always multiply with the element pattern to get the overall radiation pattern. Then we also saw what are the limits on the practical sizes of the reflector, and what is the practical limit on the value of the S which is spacing from the apex or the corner of the reflector to the let us say dipole antenna.

And this spacing even though I gave you the values which are given in the book you can take say 0.7 lambda even greater than 2, but I do not recommend that large spacing because that requires larger reflector length, but yet I strongly recommend anyone of you take this particular case do the simulation, do some experimental work and you can also write some papers in the journal also.

In the next lecture we will talk about parabolic reflector antenna which can give us very high gain. So thank you very much, with that enjoy yourself study hard, work hard. But when you come for the next lecture please study these things, because we will use the concept of these reflectors to the parabolic reflector antenna. And if you the time permits please look at the basic theory of the parabolic; what is the definition of the parabola, and you look into it that when the rays come from the infinity they focus at the focal point. So, look into those things if possible, otherwise we will look into those things in more detail.

So, with that thank you very much.