Antennas
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Module – 12
Lecture – 59
Reflector Antennas-IV

Hello, and welcome to the today's lecture which also happens to be the last lecture on Reflector Antenna. So we will quickly start with where we had left in the last lecture. In the last lecture we will looked at the parabolic reflector antenna, and we saw that OP plus PQ is equal to constant. And from there we had derived the relationship for f by d which is related to theta 0. Then we started talking about spillover efficiency as well as taper efficiency.

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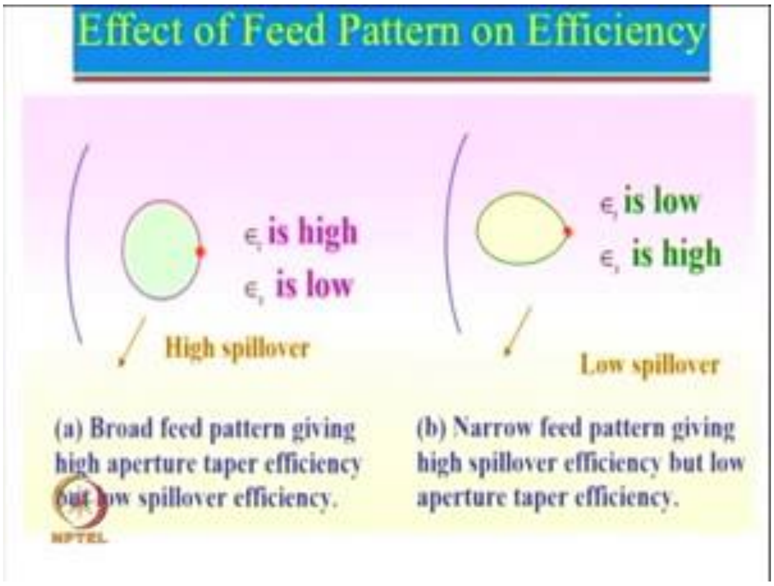

So, let us start from that particular slide, one more time just to refresh the memory. Here we have the two same reflectors, but in this particular case feed has a larger you can say uniformity here; you can see that the half power beam width here is relatively larger, over here half power beam width is relatively small. And in this case we had seen the spillover efficiency is relatively good; that means there is a low spillover efficiency. But in this particular case we had seen that there is low spillover; that means, high spillover efficiency, but the taper efficiency was relatively low.

And in this particular case we had seen that the taper efficiency is high, but spillover efficiency is low because there is a higher spillover. And we also looked at the plot of these two thing here.

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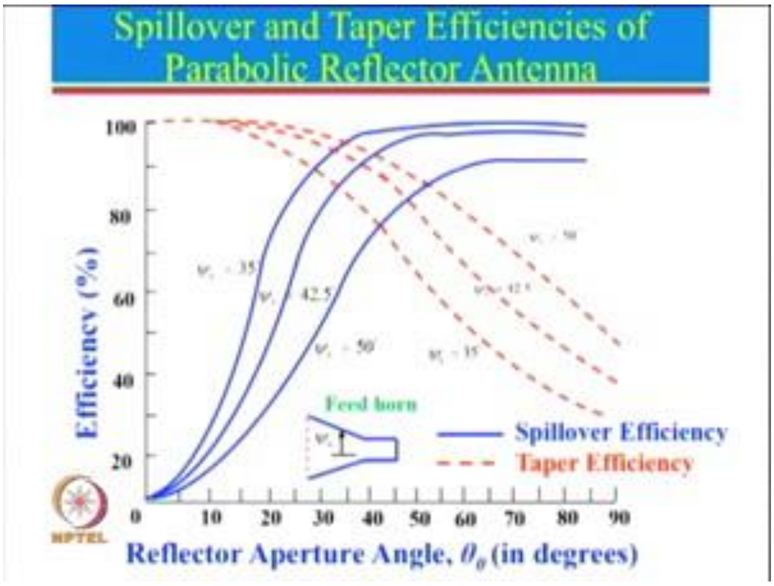

So, we can see that as the reflector angle increases, so if the reflector angle increases for the same beam pattern you can see that spillover efficiency will be very high, because if angle is increased significantly there will be very little spillover and hence spillover efficiency will be high.

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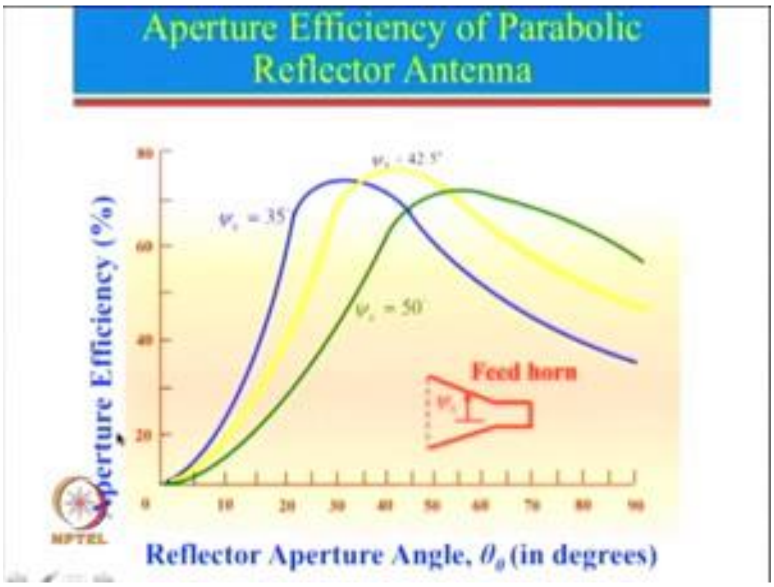

And if the theta 0 is very small; that means if the reflector itself is very small; that means it is not going to receive much and in that case spillover efficiency will be very poor or spillover will be very high. And taper efficiency is reverse of that, and the product of these two which is sometimes also defined as aperture efficiency; we saw that also. And we saw that the aperture efficiency is product of the two which starts from a 0. And somewhere in this particular region we can see that efficiency is kind of maximum, and you can see some correlation also. So, this is the half power beam width of feed horn and if you look at the line down below here, so the reflector aperture angle is also of the same order.

If you look at here this is if it is around 35 degree, you can see that this one here also corresponds for that for particular angle. Or if the half power beam width is large then theta 0 also should be large and that is where you get relatively maximum aperture efficiency.

But now the question comes that these are the aperture efficiency, but we had discussed about many other things. So, I just want to tell one more time even though it is mentioned as aperture efficiency, but this is really product of only two efficiency; which are spillover efficiency and taper efficiency.

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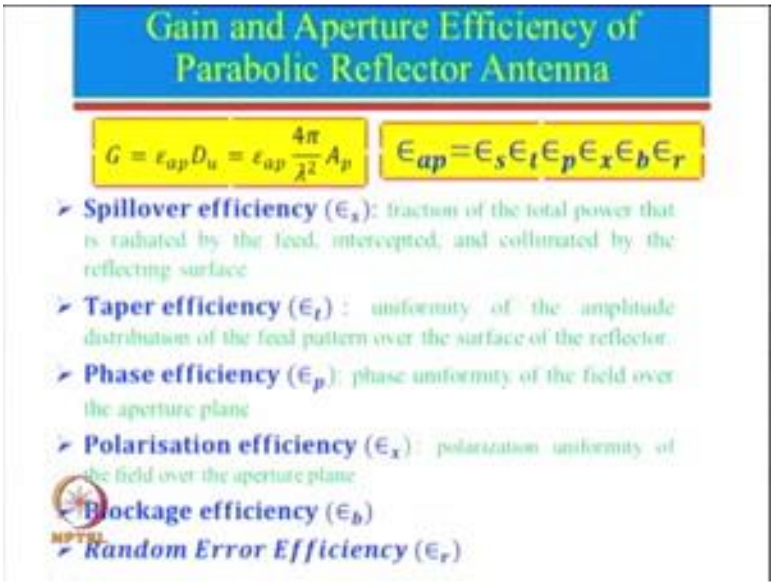

S, now let us just see; what are the other four efficiency, and where they come from, and what are their roles. Now, this is the next one here is a phase efficiency. Now where is the phase efficiency coming into picture? So for that to understand we have to actually go back and look into this figure again here.

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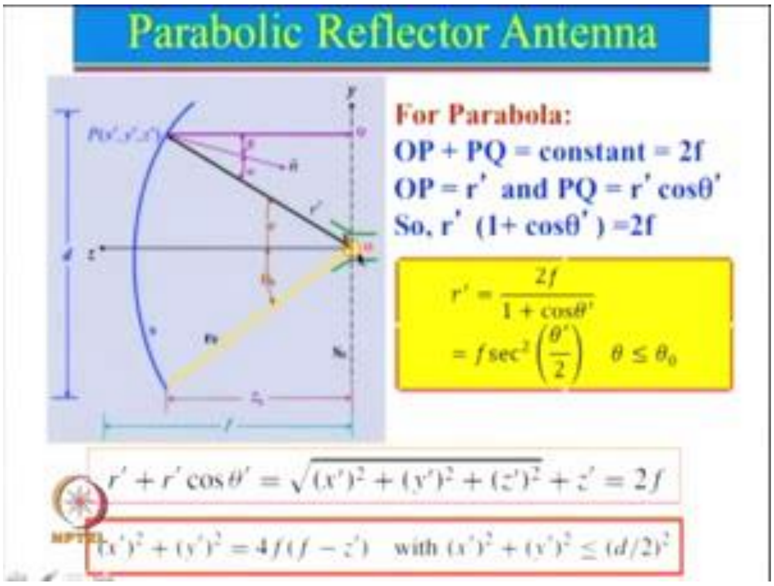

Now, what we assume that this particular thing we have designed it, so when you designed it we think about a perfect parabola right. But when you we do the fabrication, now there is a possibility that this particular thing may never be exactly the same. Now just imagine if suppose if this is a let us say 2 meter dish antenna; now if it is a 2 meter that means diameter is 2 meter. Now what is the guarantee that this particular thing we will follow exactly the same pattern. There is a possibility that this point may be at this place here or it may be this place. And the error may be relatively small in the alignment.

So, over let us say the diameter of 2 meter the possibility of having an error of let us say 1 or 2 centimetre is always there. And now what really happen? Suppose instead of this let us say this particular thing is deform or manufacturing error is there, so it is somewhere. So, if it is somewhere here; that means now this length will now be up to this point it will reflect here and then come back. That means, now this distance travelled is more compare to the distance travelled where there is a no error. And this larger distance travel gives rise to the phase error.

Now I want you to recall horn antenna discussion when we are talking about the horn antenna. What we had see that the horn antenna the phase error increases if this whole thing increases right; why? Because at this point which is the reference point and at this angle we will see that there is additional phase error. And there also we had mentioned about that if the phase error is about 90 degree; which is what many of the intentional books say 90 degree phase error is allowed, but I had mention that a 90 degree phase error gives rise to the poor efficiency, in fact that itself gives efficiency of the order of 50 to 60 percent. And if you want an efficiency 70 percent or more then the phase error has to be may be 45 degree or so.

Here let us see; what is that 90 degree that is if you go for the maximum 1 and 90 degree gives rise to almost efficiency of 0.5 or 0.6. So, 90 degree would actually mean additional length of lambda by 4. And now what we talked about this was the ideal one and because of the manufacturing defect it became like this; so that means the distance travelled will be more. And now suppose if it the error as I said even if the error is say about 1 centimetre. So, it goes there and reflects back let us say reflected back distance travelled extra is 1 centimetre, we talking about 2 meter diameter 1 centimetre actually is possible it does happen many a times if you do not do proper fabrication.

So in that case what happen, now let us see if you are working word frequency? Suppose we have working at let us say 3 gigahertz. At 3 gigahertz wave length will be 10 centimetre lambda by 4 will be 2.5 centimetre. So, this 1 centimetre error will not give rise to too much phase error so it is ok. But now think about if you working at 30 gigahertz. So, at 30 gigahertz wave length is 1 centimetre. And if you talking about 1 centimetre additional thing; that means the phase error of 360 degree and that is definitely not allowed.

That means, at 3 gigahertz that phase deviation whatever there that may be allowed, but at higher frequency that dimension tolerance is required are very very strict and we cannot allow a distance extra of 1 centimetre. In fact, for a 30 gigahertz system even a 0.25 centimetre will give rise to a 90 degree phase difference, and that will make efficiency straight way from one to 0.5. And this 0.5 will get multiplied to the rest of the term. So, the phase error comes mainly because of this particular term here.

Now let us just see; what is the next efficiency. The next efficiency is polarisation efficiency. This polarisation efficiency really depends upon the feed. Suppose if we have a let us say linearly polarise thing, so we need to see; what is the linearly polarised component in one plain and in the other plain. So, if you can design a good linearly polarise antenna or if it is a circularly polarise we need to actually see that it should have a good LHCP and not a good RHCP. So, the separation between LHCP and RHCP should be minimum 20 dB in the operating beam width.

Then let us see what are the next efficiency. The next efficiency is blockage efficiency, so let us see what that comes from. So, blockage efficiency come from let us say now this feed which is radiating the beam goes over here and reflects back. So, this particular portion of the feed will block the radiation going in the far away distance. So, basically and this area is the where, where we have the maximum radiation which is coming back over here. And which is getting block, and since it is getting block that means efficiency will get poor. So, it is always advisable things that try to design an antenna feed antenna which has a relatively smaller aperture here then it will have relatively less blockage. And in that case we can have very good efficiency.

So, in fact to reduce the blockage, many a time people do not use prime focus feed, but they actually use half side feed. Instead of putting the feed over, here feed is actually put over here and this has to be designed in a different way so that when the feed is put over here it goes like this and all the rays come out in parallel and the blockage in that case will close to 0. So, over here blockage will really depend upon the block by the horn antenna or microstrip antenna or helical antenna or whatever antenna we have used over here.

Now we have to also look at the blockage can be approximately calculated, very approximately is. What is the area of this particular portion? And then you see what is area of this particular feed here? And take the ratio of this with that and that will actually tell us what is typical blockage coming out of that. So, generally speaking the blockage efficiency can be 0.9 to 0.98 depending upon the size of the feed.

Then comes the last one which is known as a Random Error Efficiency which is epsilon r where is that coming from? Random error efficiency comes from the fact that let us see again it is comes from the manufacturing fact. So, we want a perfect parabola, and that what it really means that it should have a mirror finish. And when we use the term mirror finish, mirror finish means that it absolutely a smooth surface. But in reality when we are doing some engineering over here this surface may not be smooth it may be something like zigzag, zigzag something like that over here.

And now that zigzag may be the order of fraction of millimetre, but that faction of millimetre if self what it creates. So, if you think about this zigzag will have a little angles like this, so the wave which is coming here will actually see a different angle, and then it may try to disperse from here to there. And also that different direction may give rise to a small phase error also; you may say that phase error was accounted in epsilon P. Now that phase error was because of the deviation over here. This we are talking about random which is the randomness of this.

Basically, that can be taken in care also after the machining; what people do they use actually kind of smoothing surface of this technique. So, sometimes they do some electro plating on this particular surface so that it become smooth or sometimes they do some slant sand blasting or so, so that it can be made surface as a smooth surface. So, the ideal surface which is known as a glass finish, but reality can be different.

So, this again surface randomness error is more prominent at the higher frequency then at the lower frequency. So let us see; what are the other things. So, these are the efficiencies and when we designing a reflector antenna design basically consider these two things: most of the time these are more related to the fabrication error. And this of course is related to again the issues here, but the fabrication tolerances are directly governing the value of specially epsilon p and epsilon r. So, if we take care of these things one can design a good reflector antenna.

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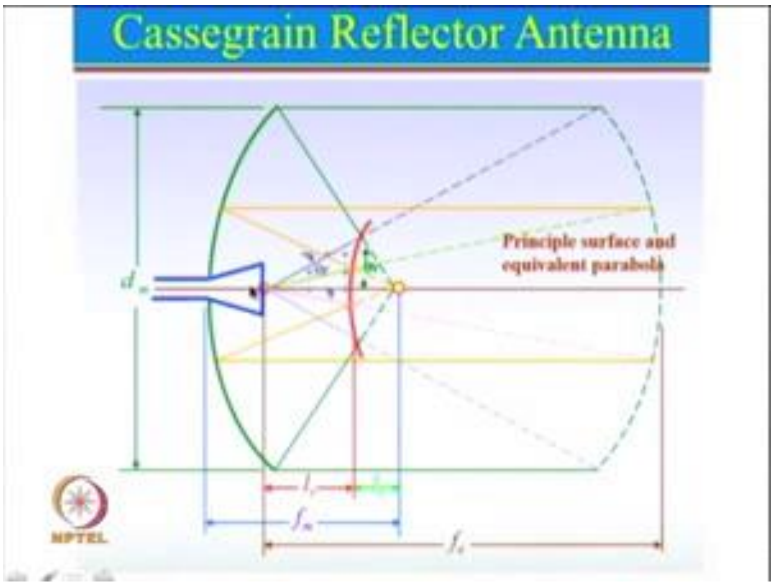

Now let us just move on to the next reflector antenna, which is actually speaking know as a Cassegrain reflector antenna. This is slightly different, you can actually see that there are two reflectors are there: there is a one this is known as a main reflector and this one is known as a secondary reflector. And here what we have the feed is put over here and then this feed radiates, so you can see that this radiates here it reflects back from this surface goes over here and then goes like this. And then this one here goes here reflects back and then goes in this particular direction.

Now you can actually see that blockage in this particular case is much larger compare to the previous case if you had put the prime focus feed here. You can see that if this was over here blockage will have been less. Then why do we use this? Most of the time cassegrain reflector antennas are used or especially for high power transition case where we may have large generators over here which could be high power source can be magnetron, plastron, gigatron and so on, and they also require large power supply.

So, generally that is put behind this particular reflector and the output of that is directly connected to this particular antenna. Basically if we had put this particular thing over here then the blockage could have been even more. Now alternatively one can think that why not we put this entire thing use a wave guide feed and then connect over here. The problem with that is since we are transmitting a very high power and even a wave guide will have some losses from this point to this point over here and those losses also will be relatively more, and also for high power heating of wave guide can also take place which may require some cooling. All of that thing can be taken here in this particular fashion here.

Now, beside this cassegrain reflector antenna there are many other configurations are also possible, I did mentioned about offset reflector antenna. In fact, many a times you might have seen; for example all these dish TV antenna which receive the signal. And these days are they typically work on the frequency band of 11 gigahertz round about. So, when they are receiving that signal, and if you see that particular thing a dish actually has a offset feed. And this is let us say pointed towards the satellite and this is the offset feed the things which are reflected back; signal coming from the satellite reflects back focus at this offset feed; that is the one of the thing.

Then another one which is actually very popular that is known as a cylindrical parabola reflector. In fact, the cylindrical parabola reflector shape is something like this here. So it has a part of the cylindrical shape, but this is a parabola. This kind of a thing is actually use at the airports, if we have gone there you might see that there is this big structure is there which is continuously rotating all around. Basically what it is doing it is looking at the incoming plains.

So, what it is really doing here? Let us say this one here this aperture is relatively small, so beam width will be large in this plane. And since this one here is a large beam will be narrow in this one. So, think about this particular thing case here. So, narrow beam in this one and a broad beam; that means now any plain which is coming or taking off will be covered here. And now it is looking at only a smaller angle, and now this is rotating and the signal is coming here. So, whenever it is sending the signal reflect back signal will come, so it will know that this particular position we get the signal; that means there is a plain in this then it is rotating. So, if you get a signal from this side. So we know that; what is the approximate distance of the plane.

Of course, in more complicated configurations where they want to know even this particular height here, so there they use multiple arrays of antennas. So, what they do it is that each of these one will receive signal from the transmit and receive and then you process it in that case you will know at what angle the plain could be. And most of the time those are use more by the defence people this one is of course commercial application.

There are also known as a spherical reflector antenna. So, spherical reflector antenna nothing but just part of a spear, but only the portion of that is used. The property of this spear is that anything which is put at the centre it goes here reflects back in this direction. Then if you put some feed here, it transmits in this side and reflects back. So, generally speaking at a given time it only eliminates its smaller portion of the spherical reflector antenna.

So, you can actually say that it uses multiple feed, so one feed is put in this reflects so beam maxima is going in this direction; another feed which is in this particular direction it goes here radiates reflects back. Generally a spherical reflector is not used for its property of a very high gain, but it is actually used one reflector with multiple feed so that you can look at different beam angle.

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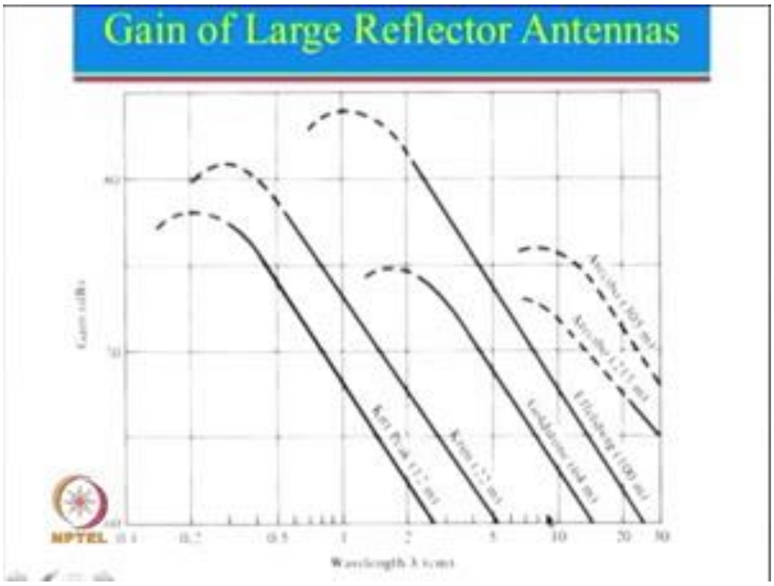

Now let us just look at what are different types of large reflector antennas available in the world. Let us see what we have here: this is the gain in dB you can see here this is 60 dB, 70 dB, and 80 dB. 60 dB as I mentioned earlier is 1 million, so gain is very high. What we see here is a wave length which is varying from 0.1 to 30. So, 30 centimetre wave length corresponds to 1 gigahertz and this one here 1 centimetre corresponds to 30 gigahertz.

So, let us just see here these are the two antennas which are actually in (Refer Time: 20:24) which is in (Refer Time: 20:26) area and see the size this is a 215 meter diameter and that say 305 diameter. That is really huge humongous antenna, and generally these antennas are working at the lower frequency range. You can see this is 1 gigahertz, this is 3 gigahertz. Then you can see that this is relatively smaller, but not really very small still like 100; and you can see what is the gain. At here there this is a 60 dB gain it is going all the most close to 80 dB gain here. And you can see this are the different things here.

Now you can see one interesting thing that all these things are increasing linearly which should actually happen, if we are reducing the wave length; that means increasing the frequency. But you can actually see that at this particular point you can see that the gain has started reducing. So, even though wave length is reduced and if the wave length is reduced directivity should have increase or gain should have increase, but it not increasing it started decreasing. And these are the typical problems which are arising due to the phase error problem as well as random error problem. So, those are the main thing which reduces. So, these are the typically very large reflector antenna. And I can tell you that this kind of gain is only possible with the reflector antenna and not possible with the any other type of antennas.

Now I would like to conclude the entire course. This particular course we started with the simple fundamentals of antenna. So, we talked about VSWR, we talked about input impedance, we talked about reflection, and then we talked about the radiation pattern, we talked about the cross polar, we talked about first null beam width, and then we talked about the gain, gain relation with the aperture. So, these were the basic thing we talked about fresh transmission equation which is very very powerful equation to do a link design or link budget.

And after that we talked about the very basic antenna which is known as a dipole antenna. And we saw that the radiation pattern of the dipole antenna varies if you keep on increasing its length. And of course, most popular one is a lambda by two dipole antenna, because it is a resonant structure. We saw what is the input impedance; we also looked at the design how to design a dipole antenna for a real input impedance. And if you recall the formula we had seen was l plus d equal to 0.84 lambda and if you use that you can design a dipole antenna. We also saw the band width professional to the diameter of the dipole antenna or alternatively we can use conical dipole antenna.

And then we talked about the monopole antenna. First we discussed about monopole antenna on infinite ground plane, and we know that there is nothing like an infinite ground plane. And then we talked about monopole antenna on finite ground plane, and there we saw that the finite ground plane plays very very important role, and the size of the ground plane really speaking controls the input impedance of the monopole antenna and also the gain of the monopole antenna and radiation pattern.

Then we talked about slot antenna and loop antenna. Slot antenna is nothing but the compliment of the dipole antenna, and loop antenna can be thought of as a magnetic dipole antenna. And we had also mentioned that majority of the time we use loop antenna which are smaller in size and we generally do not use large loop antenna. After that we talked about linear planar arrays. In the linear arrays we initially talked about uniform amplitude distribution and then we saw different different characteristics. We saw how to calculate the radiation pattern, how to calculate side loop levels, how to calculate first level beam width and so on and so forth.

And then from there to we went to talked about uniform, from uniform distribution to non uniform distribution. So, we saw that there is a triangular distribution cosine distribution, cosine squared distribution. And basically by using these distributions we can we could actually proof the side loop level, and of course side loop levels reduced but gain reduced slightly. After that we talked about planar array. And we saw that how we can control the beam width in both the plane E plane as well as H plane. After that we talked in length about microstrip antenna. The reason for that is microstrip antennas are becoming very very popular their gives many conventional antennas and that is why antennas has been lot of focus and microstrip antenna.

So, we talked about several different things in the microstrip antenna. We started with the simple basic configuration like, rectangular, circular, triangular shape. Then we talked about broad band microstrip antenna and where by adding parasitic elements in the planar dimension or in the vertical dimension or both planar and vertical we could increase the band width typically 2 to 5 percent to all the way to 20 percent 30 percent or even more. Then we also talked about circularly polarised antenna, we talked about compact microstrip antenna, we talked about multi band microstrip antenna. And after that we concluded microstrip antenna with various microstrip antenna array configuration.

After that we talked about helical antenna, and we looked at two different modes of helical antenna: normal mode and axial mode. And generally speaking normal mode is a nice replacement of a monopole antenna and the axial mode helical antennas are generally used for circularly polarised antenna configurations. And then we talked about horn antenna and we emphasize that the phase error of 90 degree and 135 degree is not acceptable. And in general you should design for a phase error of may be 45 degree and not more than that.

And after the horn antenna we talked about Yagi-Uda, and law periodic antenna, and we saw that Yagi-Uda antennas are generally used for high gain applications, and law periodic antennas are generally used for broad band application. And nowadays lot of research is going on we are combining the benefits of Yagi-Uda and law periodic antenna. So, that is a very good research topic you can look into that also.

And then we concluded the whole thing by covering reflector antenna. So, where we talked about the plane reflector antenna, we talked about corner reflector antenna, and we talked about the parabolic reflector antenna. Now I also want to tell you there are many other types of antennas are there. For example, as a lens antennas are there, there are spiral antennas are there and many other things. But in this particular course it was not possible to cover each and everything, I actually felt that it is better that we understand few antennas in depth and then once you have understood some of the antennas properly you can apply the same concept to understand other types of antennas.

So, from my side I try to give also the practical part of it or generally speaking the emphasis was on the design of the antenna. In fact, our prime minister has been emphasizing make in India, in fact I have actually added a line before that: before make in India to happen it has to be designed India, 'so until unless we do design in India what are we going to make in India'. So that was the whole crux of my course that focus on the design of the antenna, will also show you some practical antennas in our lab and will show you how we do the measurement of some of the antenna parameter.

So with that best of luck, I hope you enjoyed the course on antennas. And hopefully you design your own antennas, fabricate your own antenna; and these antennas are required by all you can say telecom industry, they are required by the space industry, these are required by the (Refer Time: 29:30) also and this is big where required by the defence industry. So all the best, and have a nice time in designing these Antennas, bye.