Antennas
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Module - 08
Lecture - 37
MSA Arrays – I

Hello and welcome to today's lecture on micro strip antenna arrays. So, we just want to take you little backward and if you recall we did discuss about array theory. So, when we discuss about array theory, we started talking about linear array and there the first thing which we started was let us take linear array with equal amplitude and equal phase. And then we looked into how we can calculate half power beam width, how we can calculate gain, how do we see radiation pattern and so on and so forth. And then we also looked at the, if there is a phase variation what happens, then beam can be changed. So that a scanning beam antenna array can be utilized.

After that we also looked at the non uniform amplitude distribution and the advantage of using non uniform amplitude distribution. Some examples which we had seen was cosine distribution, triangular distribution, cosine square distribution and by using this distribution the advantage was we could reduce the side lobe level, but at the expense of reduce in the gain also. Then we also looked at the planer array. And now in the last several lectures we are talked about micro strip antenna. So, we actually looked at a simple rectangular micro strip antenna, then circular, then triangular, then we looked at broadband techniques and after that we looked at compact micro strip antenna techniques, then tunable antennas, dual band antennas and then we also looked at compact micro strip antenna.

Now, for all those cases which we discussed earlier typical gain can be maybe 5 dB to say 9 to 10 dB or for gap coupled configuration we could see you could get 11 or 12 dB, but there are many applications where we need an antenna of gain of may be 20 dB, 30 dB, 40 dB, 50 dB; however, micro strip antenna arrays cannot give us about 40 dB on its own. So, generally speaking micro strip antenna arrays are very popular up to gain of about 30 dB and anything to be done beyond that it requires very special care, precision and lot of innovative thinking. So, today we are going to talk about micro strip antenna arrays. Will start first with the series feed and then will talk about corporate feed. So, let us discuss today's topic which is micro strip antenna array.

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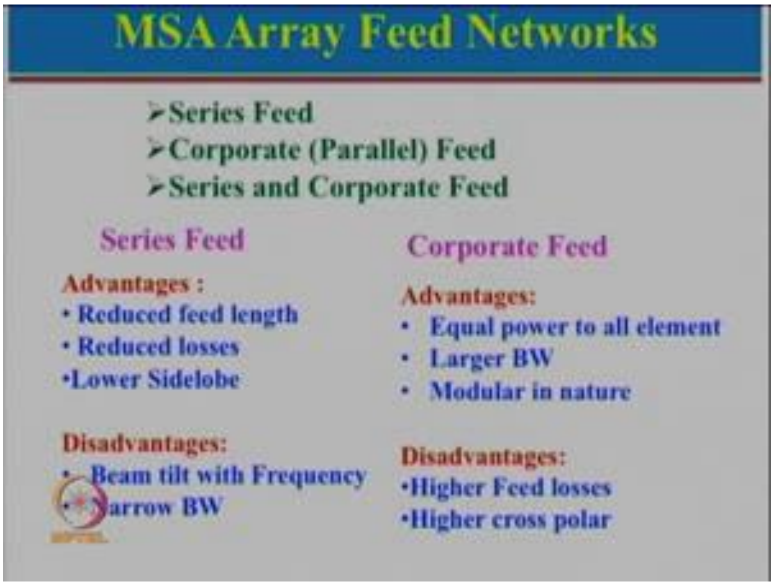

So, now, for micro strip antenna array, the most important thing which you really talk about is how do we feed different elements. And array is suppose to consist number of elements. So, at the array size is determined by the number of elements. So, suppose if you have a linear array then, all the array elements are arranged in a linear fashion or we call it a planer array where, all the elements are not just in the linear fashion, they can be in the different different configuration. They can be in rectangular configuration, they can be in circular configuration also, they can be in hexagonal configuration also. Now for all these cases then we need to design proper feed network. And this feed network has to be design properly depending upon the requirement suppose.

We need to feed all the elements with equal amplitude, which has an advantage of highest possible gain, but it has a disadvantage of that side lobe level we can get is only about minus 13 to minus 13.5dB. There will be radiation from the feed network which may actually increase the side lobe further. So, then we also use sometimes the amplitude distribution so that we can get a better performance from side lobe level point of view. So, depending upon the type of array, is it a linear array or a planar array we need to design the feed network accordingly. So, let us look at how do we feed these antennas? So, there are different techniques to feed these antennas. So, the feed techniques are one is a series feed; that means, suppose you have a patch here you have another patch you can connect these patches in series. So, let us say we have a one patch then another then another. You keep connecting them in series.

Another possibilities you connect these patches in parallel. So, for example if there are two patches and in fact it parallel is also known as corporate feed, how is the corporate world was? So, for example, let us say if you take an example of IIT Bombay. So, we have a one director then, there are two deputy director, then under these director there are multiple deans are there. Then under multiple dean there maybe multiple head of the department and then after that there are multiple number of faculty and then after that we have nearly 10000 student. So, that is what the corporate feed is. So, you start with one and let us say that top here will be divided into two, then we can actually feed two patches. Then these two can be further divided then, that will become 4, 4 can be divided further into 8. So, that is a normal thing which goes like 2 to the power n. So, 1, 2, 4, 8, 16 but that is not always the requirements. Sometimes we need different type of elements or different number of elements depending upon the space requirement. We need to optimize number of elements to fit in a given space.

So, lot of thinking has to be done where we need to actually speaking feed all the different elements and which may not follow the concept of let us say 2 to the power n. So, sometimes we use series feed where, we can connect them directly. Sometimes we use corporate feed where it is like a corporate structure also known as a parallel and sometimes we have to use combination of these which are known as series and parallel network. So, these are the different possibilities are there series feed, corporate feed, series and corporate feed. So, let us first look at what are the advantages and disadvantages series and corporate feed?

So, one of the major advantage of series feed is, it has reduced feed length because the elements are connected in series. Whereas, incorporate the length is much larger and since the feed length is smaller there is a reduced losses are there. And also in the feed, series feed we will see that it actually gives rise to lower side lobe, but that also again depends how properly you design the feed network. The disadvantages that there can be beam tilt with frequency, especially if you use end feed series array and in general it has a narrow bandwidth.

The reason for that is that when we use series feed. So, one element, then second, then third there is a phase delay happening across the patches and that gives rise to narrow bandwidth. In case of corporate feed what are the advantages? Generally speaking corporate feed is designed for equal power to all element, but this is not always true corporate feed can also be designed to give unequal power also. But this is most common thing. Now corporate feed in general has a larger bandwidth compare to the series feed and this is modular in nature; that means, suppose you have designed a 2 by 2 array then, making a 4 by 4 array is relatively simple. Just use the concept of 2 by 2, extended to 4 by 4, then 4 by 4 to 8 by 8 or 4 by 8 it is relatively easy. Similarly from 8 by 8, you can go to 16 by 16 from 16 by 16 we can go to 32 by 32. Now 32 by 32, we are talking about 1024 elements. Now majority of the time people actually stop there.

Because after that if you start increasing, the feed looses become very very large. So, there in general then what is done? You take a one; let us say full module of 32 by 32 another module of say 32 by 32. These can be arranged in 2 by 2 configuration, which will give rise to 64 by 64 array or 32 by 32 can be put in this way and then generally external power divider network is used to feed these arrays. So, that is a general convention, so that the feed losses which are going to be on the same substrate can be contained. So, it is modular in nature, but what are the disadvantages? Now basically the disadvantages since it has a higher feed length so there will be higher feed losses and also there will be radiation from the feed network. And hence it gives rise to higher cross polar also and sometimes to higher side lobe level also.

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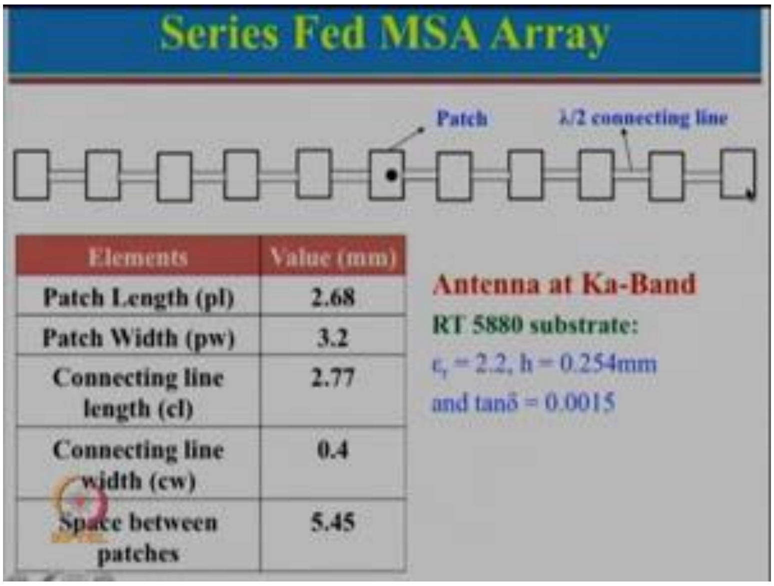

So, let us start with an example of a series feed micro strip antenna array. So, what we have here? You can see that here we have a number of patches here. So, we can just count here 1, 2, 3, 4, 5 then there is a central element and there are 5 elements on the left side so 5 here 5 here. So, total number of elements are 11 and this generally uses this particular configuration uses all the number of elements. So, that with respect to the feed it has its left hand symmetry as well as right hand symmetry then now comes the next part, this one here is the radiating patch here. So, you can see that the radiating edges are connected to the next patch. Now generally we know that the patch length is approximately equal to lambda by 2 and suppose for feed is here we generally say this is plus, this is 0, this is minus.

So, this is plus, 0, minus and we want the same thing over here plus, 0, minus. So, now, this is plus, we from here we want this to be minus and that can be achieved by using a lambda by 2 connecting line; that means, the length of this particular connecting line should be approximately equal to lambda by 2. So, then what happens? So, this is plus, 0, minus because of this length to be lambda by 2, this plus will become minus. So, this minus then this is plus, then plus here becomes minus, minus becomes plus. So; that means, now all the patches have pluses on this side, all the patches have minuses on this side. So, they will be radiating in the broadside direction and hence they will give rise to better gain. So, over here now the next part is what should be the characteristic impedance of this line? So, we know the length should be approximately lambda by 2. Now why again I use the term approximate?

Why not exact lambda by 2? The reason for that is that the fringing feed is also there. So, if you look at the equivalent configuration of this one here. So, what the fringing feed will make it? The effective length will be something like this, it will go up here then it will come here. The fringing field will be like this going up here and like this here. So, that is why the effective length should be lambda by 2, effective length of this should be lambda by 2. Not the physical length of this and this should be lambda by 2. So, effective length is important and that is what gives rise to phase shift from here to here, which is 180 degree.

Now as I mentioned the next thing. So, what is important is what should be the characteristic impedance of this particular line here; that means, what should be the width of this line? Now if you apply transmission line theory. So, in the transmission line theory we know that concept is that a transmission line which is ended with the load z n and this length is if it is lambda by 2 then input impedance of that line is equal to z n. It is not dependent on the characteristic impedance of the line.

So, we try to use the same concept. It does not depend upon the characteristic impedance of the line so; that means, you can choose any width, but that is not really correct over here. So, is transmission line theory wrong? No definitely not. Transmission line theory is correct that if the length is lambda by 2 and the load is z n, input impedance will be equal to z n, but over here the loading effect is making changer. So, let us just look at this configuration one more time. So, what is happening? Think about this, if this width is very large; suppose it covers over here the whole thing. So, is this patch then of length l? Not really if it look like that whole thing is a one big patch over here. So, now, suppose if this characteristic impedance is relatively high. High would mean this width is small. So, what will happen? There will be more fringing field from here, but if this width is little large then there will be lesser fringing field over here. So, what really happens?

Because of that this actually line acts does loading to this particular patch not only that. In fact, the design of series feed micro strip antenna is much more complicated in a sense that suppose we take a this one here. Then we add let us say these two patches and in that cases suppose if we just think of three element, then this is not there. If this is not there; that means, this side is not loaded. So, this will at does not open circuit. So, that loading over here will be different, but now suppose we just add one more patch here, this is suppose not there. So, now, this season open circuit, but this seize over here a loader line. So; that means, the impedance of this then loaded over here then comes over here and the same thing happens over here.

So, as you keep on adding more number of elements. So, what actually happen? The loading effect of that reflects over here and that is why one has to really properly optimize the patch length as well as the connecting length as the number of elements change. And now I am going to show the design example at Ka Band. A Ka Band actually corresponds to the millimeter wave band and. In fact, the band here which we have chosen is about 34 to 36 gigahertz. Just to tell you a millimeter wave band is very large it actually its goes from 30 gigahertz to 300 gigahertz. And millimeter wave band today is become very very important. Especially with the advent of IO Team which is internet of Team. They are talking about using millimeter wave communication. Then there is another thing which is coming up that is 5G. So, 5G is also going to use millimeter wave communication. So, there are lot of advantages and disadvantages of using millimeter wave configuration.

So, one of the major advantages that; the size of the antenna at millimeter wave is very very small. I mean just think about it compare to 3 gigahertz, if you have to design antenna 30 gigahertz; frequencies increase by 10 times; that means, the patch length will reduce by 10 times. So; that means, in a very small aperture you can accommodate an antenna or in the same aperture you can actually accommodate compare to 3 gigahertz you can accommodate 10 times more of the antenna; that means, gain realize can be very very high. So, that is the major advantage of millimeter wave; the second major advantages the bandwidth available.

So, for example, in the millimeter wave what we have bandwidth available is say let us say from 34 to 36 gigahertz, but even you can extend that. Now, but just 34 to 36 Giga itself, is a 2 gigahertz bandwidth and we can accommodate lots of channel. We can actually talk about of very large bandwidth, very large data rate. People have been talking about having a data rate of 1 gigabits per second. So, think about a movie which maybe having a 1 gigabit you can download that movie in just about 1 second which may take few minutes today. So, data transfer will be very very fast, but at millimeter wave, we have to be very careful about some other problems associated with it and the one of the major problem is the path loss is very high. And especially rain attenuation is very very high.

So, during monsoon propagation in the free space maybe very less because rain attenuation will be really large. So, there will be lot of absorption will happen in the water molecule of the rain, lot of diffraction will happen and also in millimeter wave there are lot of bands are there where it has a very high absorption also, for example, just to mention. So, 34 to 36 gigahertz there is a lowest absorption in that particular range. Then at 60 gigahertz there is a very high absorption. Then at 94 gigahertz there is a lower absorption, then at 140 gigahertz there is a lower absorption, then at 220 gigahertz there is a lower absorption. So, you really speaking if you want to use communication then you have to select these bands where there are lower absorption.

Yet at around 60 gigahertz it is very very popular where, the absorption is very high. So, now, you might wonder why 60 gigahertz or 67 gigahertz is very very popular. The reason for that is the precisely the same thing that it has a very high absorption. So, if it has a high absorption just think about that let us say we are in a room and in that room there are multiple gadgets are connected and all these gadgets are connected with the wireless router. So, that would mean that let us say a computer can communicate with another computer without connecting the cable computer can communicate with the printer and the data rate will be very very fast or so many devices within that room can communicate with each other wirelessly. So, now, that information is freely available here. So, we do not want that information to be heard or to be tapped by the people outside, just because of the very high absorption.

So, what happens? The distance travel will be less. So, outside the room or the office or the lab the signal will attenuate very significantly. In fact, about 4 years back I had gone to Kashmir in India and there it was very interesting thing happened. Or I just tell you little diversion from here, but then you will realize the importance of millimeter wave and also why I am telling you that that; why 60 gigahertz is very very important? So, just the little diversion here, around 4 years back me and my family went to Srinagar because one of my army student who was posted there, they had some requirements about antennas and mobile phone jammers.

So, we went there and at IIT, we get LTC. So, I took LTC, took the whole family over there and just before going I remember we went on first June and just previous night around 11, 11 30 PM mu this student, who was a first, a Lieutenant Kernel there. He called me and he said Sir, there is a one small problem. I said what is that? He said curfew has been imposed in Kashmir and then he said still; Sir please come, we will make arrangement. Now I did not want to tell my family something like that is there. I said since my student is telling and he is from army they will take care of it. So, when we all went over there when we were about to land in Kashmir.

So, we could see the roads which were all vacant and there all saying oh you know all these vacant road empty roads are there I did not want to tell them, that it is because there is a curfew in Kashmir. So, when we came out you know the air was so fresh you know it actually really felt you know that you have really come to heaven; absolute fantastic clean air. So, you know we just took lot of breathing and you know felt good about it. So, when we came out and then you know you could see there were very few people and then my family came to know that there is a curfew. But this so person who had come in the civilian dress he said do not worry we will take care of it. Well that worry was there, but let me tell you. So, what happen? So, from there and we have to go to Baramulla place where this particular officer was posted.

So, from Kashmir we were going towards this, on one road which we took we saw that the road was totally blocked. The driver said - do not worry, then we took another road. On that particular road we saw now that was a lot of smoke was there and people were burning tires and all the other things. He said do not worry sir, we will take care of it and then he took another now bumpy road. So, we went over there and then suddenly he saw that to another riots were happening there and then we actually took a shelter in one of the Kashmiris house. They were very nice, very cordial people.

So, we spent some time with them and then suddenly driver came he said lets go over there and then we moved we reached safe and sound there and then because it was curfew. So, these army people we had done the work. So, during the day we did the work and then they said Sir Abhi the work is now over, let us just look in to some other thing. So, then we went; we saw the bunkers, we saw all those different very interesting things which as a civilian we would never see and then they took us to the place which is Aman Setu; this is right at the border. And at that place between the India border and Pakistan there is just a very small bridge and all along the way. So, this people kept on explaining us. So, there was only a one river which was flowing. So, on this river India was on this side and Pakistan was on the other side and then when we went over there at Aman Setu.

So, one of the person actually gave one binocular to my daughter, this is you ok you see and through that binocular I also looked into that. So, we could actually see the people who were in the Pakistani side. So, when we are looking at the binocular we noticed that they were also looking at the binocular. So, we were actually looking at each other through binocular. So, they waved hand and we waved our hands and then some people came out from there, then over here we were just saying. So, it was really even now we were across two different countries that the border was very small, but you know it actually look like that you know you are just waving to your friends over there. So, I think people are nice. So, it is not that we had a problem, but they are only I was thinking about because these people were talking using their walkie talkie and other thing. Now walkie talkie if we are talking, then the range will be much larger. So, whatever things you are communicating within let us say in Indian army that can be heard by the Pakistan army.

So, that is where I started thinking about why not we use millimeter wave communication. So, suppose if we had use this 60 gigahertz band then they could communicate in their area and across the river or across that bridge, signal will not be going to that particular side. There will be a huge attenuation. So, millimeter waves do have some good application size is small data rate will be very very fast. So, let us just see now what we actually realized so after that diversion? So, we designed the antenna at Ka Band and over here, one can actually see that the substrate thickness is very very small. It is just 0.254 millimeter. In fact, it is a very thin substrate, if you do not handle it carefully it actually can bend also and the lot of works can be seen over here. So, it has to be handled very carefully. Why such a small thickness? If you recall when we were are talking about micro strip antenna.

I did mention that h should be less than 0.06 lambda and at Ka Band lambda is very small. So, 0.6 of lambda will be also very small. So, now, at this particular frequency and for these substrate, we calculated the length of the patch, width of the patch using the standard equation which we saw when we are talking about rectangular micro strip antenna. The connecting length has been taken approximately equal to lambda by 2. We chose connecting line width 0.4. In fact, we did study the effect of the width also. So, we vary the width from 0.2 to 0.5 and then we felt 0.4 is a good option and the space between the patches which is centered to center spacing is about 5.45.

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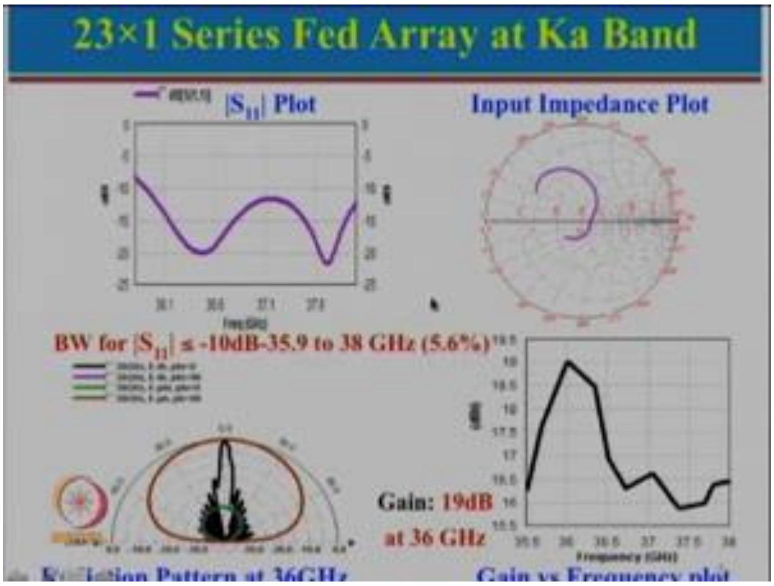

So, let us see what results we got over here. So, this is the S 11 plot, you can see that this is the bandwidth over here. If you look at the number this is almost 2 gigahertz bandwidth. So that is a very large bandwidth, but if you really look at a percentage it is only about 5.6 percent here, but that much bandwidth is available to us. So, that is the impedance plot. You can see that this is the plot which is the radiation pattern plot at 36 gigahertz. You can actually see that the side lobe levels are relatively low, but there is a one small problem; you can actually see that the gain is fairly decent which is about 19 dB, but you can see that the gain bandwidth is relatively small.

So, you can see that the gain is decreasing. So, why this is happening? And why this is giving us a good thing? So, let just go back look at the configuration one more time. So, let us say when we feed over here. So, what happens? From here the let us say power travels this side also and this side also. So, from here let us say then this patch. So, this will also radiate little bit part of that power will go there, then this will radiate little bit part of that will go here, then this will radiate part of that.

So, basically what happens? If you think about this has a maximum power, if I put over here maximum and then as we move along the power will keep on reducing. Same thing happens over here power will keep on reducing. So, this actually gives us a natural you can say taper distribution. So, since it is a amplitude is non uniform changing it like this here it gives us the lower side lobe level. Now there is another reason why we choose at the center? Why not we feed at the end over here? There is a reason. If we feed at the center then what happens? All these patches even if you design perfectly lambda by 2, but that perfect will happen only at single frequency. So, we can say that at single frequency all of them are in the same phase, but if frequency changes what happens now? Let us say this will see a delay of say suppose say minus 5 degree, this will also see another minus 5, another 5.

So, what will happen? Because of that beam will try to tilt in this direction. Now this side will also see this similar phase delay then the beam width try to shift in this side. So, one side is trying to shift on this side another is trying to shift on this side. So, with the result in that there beam be remains maximum in the broad side direction, but that happens only over a smaller bandwidth. So, as the bandwidth increases, phase error increases and then you one actually sees a split in the main radiation pattern. So, we will continue from here in the next lecture.

So, in the next lecture we will see how series feed behave if you feed at the end or you feed in the center. Then will see how corporate feed can be used, how corporate feed needs to be design for different configuration. Then will also look at smaller corporate feed and a larger corporate feed also and then will look at the combination of series and corporate feed. So, with that thank you very much will see you next time, with more arrays and feed networks, bye.