Antennas
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Module - 08
Lecture - 39
MSA Arrays – III

Hello and welcome to today’s lecture on micro strip antenna array. In fact, in the last couple of lectures we talked about different types of feed network, we looked into series feed micro strip antenna array. Then we looked at the corporate feed micro strip antenna array, then we looked in to the combination of series and parallel feed, but let us just look at today and array which does not require any feed network as such, the feeding style is very different.

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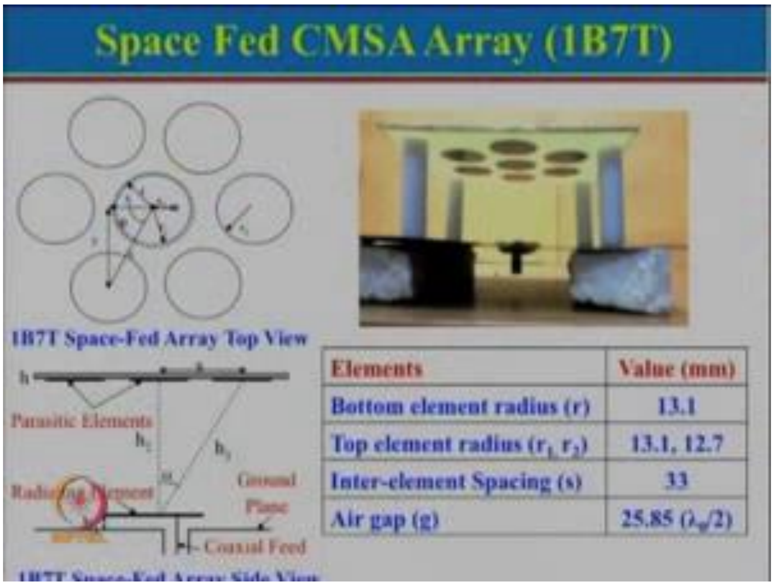

So, let us start with the today a topic is now space fed micro strip antenna array. In fact, this is actually a much later version, in the beginning we actually started with the rectangular micro strip antenna array. So, instead of using circular patches we had use the rectangular patches, but I just want to tell you how we came with the space feed micro strip antenna array.

So, actually just to tell you, there had been now problems when you have a larger array, which require large gain that would mean really that the feed network becomes very complicated the losses in the feed network become very large. So, during those days when we noticed that is a new concept came which is known as a reflect array concept. Basically reflect array was the concept which was kind using a reflector and array. So, in that what they had done just to give you the little bit background. So, for example, there is a reflector antenna. So, this reflector antenna would require a feed over here. And then let us say it is a parabolic reflect or so. The feed will radiate and then it will go in the parallel direction or the signal coming from the parallel direction will focus at the focal point.

When we discuss about reflector antenna will discuss this thing in more detail, but now the problem with this particular configuration is it occupies lot of space, and specially for let us say satellite which has a relatively smaller size they do not like this reflector antenna which occupies too much space. So, that is how the concept of reflect array came into picture, where what they had done was they actually use the concept of that micro strip antenna array, but instead of feeding all the element what was done was that let us say you exide this array using this, let us say it can be micro strip antenna feed or horn feed and this one goes over here now it is in plane. So, what happens? From here to here it will see one distance, but from here to here it will see slightly different distance.

So, what they had reported was that they actually use the different phase shift. So, that this one receives a different phase and the element here at designs such a way that it gives us the relative phase shift. So, we looked into that it looks very interesting thing we started seeing how it is, but then I noticed that they efficiency of these antennas is not very good and then we also read that they were talking about the blockage with this particular feed point. So, we came out with the concept that why feed like this and then this whole thing is radiating. So, why not we feed this particular array from the down below and will have a ground plane and this will radiate and it will radiate further. So, there is a no aperture blockage at all. So, that was the thought process with which we started working on it and then let us see what we got, just to explain the concept here. So, here is a ground plane on this ground plane.

We have this micro strip antenna which is fed over here it is only one of the patch which is being fed, and now this patch will radiate in this particular direction which is the broad side direction. So, now, suppose if we have number of elements and I am not right now saying rectangular or circular it can be any of those configurations. So, we have a number of elements over here. So, now, from here to here you can actually see that this distance is h 2, but for this element here that distance will be h 3. So, this distance is more than this here so; that means, this element will receive additional phase delay compare to this particular element. So, that additional phase delay can be compensated by taking this dimension slightly shorter than this particular dimension over here, and by doing that one can actually design this particular array.

So, here just to mention in the beginning we had taken a rectangular patch here or circular here and then we had used let us say a 3 by 3 array in the beginning, and then we went on to use very large array also, but then there was a problem in using the rectangular array because in the rectangular array if you just imagine there is a rectangular array like this 3 by 3 element.

So, if you can just imagine that then this element this one and perpendicular here and here they will be at the same distance from the central point, but for that 3 by 3 array the diagonal elements will actually see different phase difference. So, they had dimensions also will be different. In fact, we did too lot of work on that, but then we felt this is a better configuration. In this particular case what we have we have a central element here and these 6 elements you can call them they are placed in the hexagonal formation or you can even say circular array also. So, we have given the name of this as 1B7T where one patches at the bottom and the 7 patches are on the top.

So, here what we need to do the central patch will set the reference and these surrounding patches will get additional phase delay that is to be compensated by reducing their dimension. In fact, after this 1B7T we had also done 1B19T also where 12 elements were put along this here, but let us first understand the concept. So, in this particular case we had designed this particular antenna, and you can see that bottom element radius is about 13.1 central one here in the top is 13.1, but the side one are about 12.7 inter element spacing is taken to be about 33 between this, and this which will be same along all the directions and the air gap between the this and here it is very important, that this air gap should be about lambda 0 by 2, or it can be n times lambda 0 by 2 now this is very important because only then the radiation in this direction will add up with respect to this over here.

So, this distance is a very critical component in this entire design. I am just to tell you how we did the realization here. So, over here one can actually see which is very difficult to make out here. So, there is a small patch over here this is the ground plate this is small patch here which is corresponding to this here, and that is only patch which is being fed there. One can see all these 7 elements which are printed on this substrate only on one side the top side can act as a red ohm, and these are supported by 4 dielectric screws. So, that you know they can be suspended in the air. So, let us just see the results of this particular antenna. So, the antenna was designed in the c band which is from 4 to 8 gigahertz.

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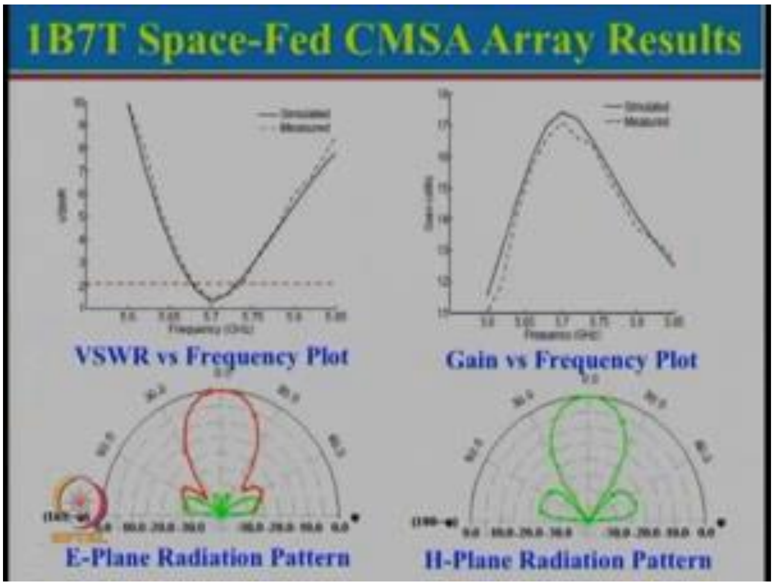

So, here you can see that resonance frequency is around 5.7 or so. And that is a VSWR 2 line. You can see that the bandwidth of this particular antenna is relatively small and even the gain pattern is like this here which shows relatively small bandwidth you can see corresponding to this the p gain is around 17 dB or so. And the gain variation you can see would be something like this which would be about one dB gain variation. So, but this particular thing has a nicer thing also that radiation pattern is relatively symmetrical. You can see a side lobe levels are very small.

You can see that over here side lobe level is less than 20 dB; over here also it is less than 20 dB. So, why side lobes are less I will go back here let us just look at this one more time. So, now, if look think about this patch here. The maximum radiation is in the broad side direction, and this one will have a something like a beam like this. So; that means, this element and this element will receive slightly less power compare to this element over here. So; that means, it will provide a natural taper distribution and hence side lobe performance will be good. So, this configuration has an advantage of a natural taper distribution. Now as I mentioned we have just seen the results of 1B7T.

We have made it to 1B19T also it can be expanded more. And this kind of array is extremely useful specially for high frequency. Now just to remind let us just see here this antenna was design around 5.7 gigahertz and the spacing over here is about 25.85 millimeter, but instead of say 5.7 let us say if we go to millimeter wave in the order of say 35 all these dimensions will be reduced correspondingly and that hide will reduce to almost close to 5 mm, also which is still fairly compact and also this does not require any feed network.

So, this is a very good array specially for higher frequency, because at higher frequency this total height will be relatively small. And this can be extended too much larger array and we can also get a natural side lobe level performance also or reduction in the side lobe level. The only disadvantage with this particular configuration is it is relatively narrow band. So, there is a lot of research potential which can be used to improve the performance of this particular array, but there are several other advantages are there let me just go back now.

This particular element actually you can do wonderful thing. For example, if you use this particular element and we feed here and suppose here, that will be suppose if we feed one angle 0 this also one angle 0, then we can actually get that dual polarized micro strip antenna or orthogonally polarized micro strip antenna array which can be used for memo application. Or this element can be which is this bottom element can be circularly polarized antenna then all this effect will be a circularly polarized micro strip antenna array so in fact, we will take one example where we will see an example of orthogonally polarized array. And will see that it becomes very complicated feed network, but this space fed antenna array can really solve many of those problems. So, let us just look at another possible configuration. This is the series fed array of gap couple rectangular micro strip antenna.

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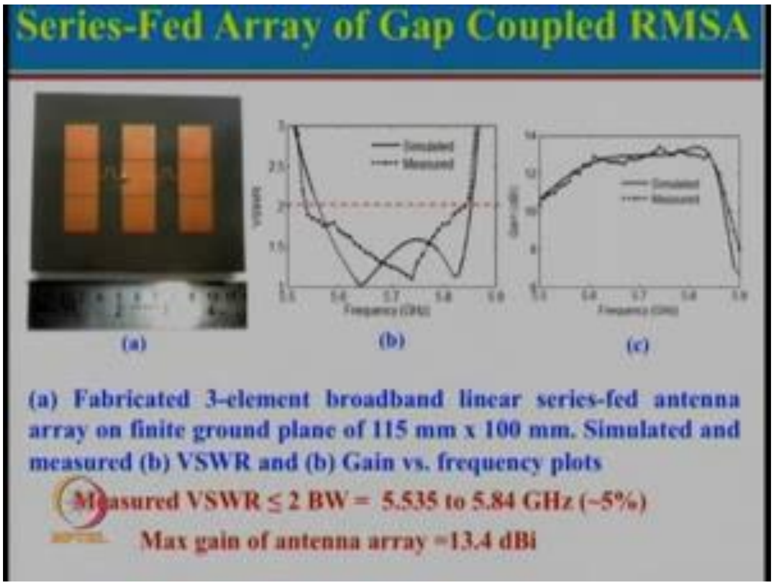

So, we have already seen this particular configuration. This configuration is known as non-radiating h gap coupled micro strip antenna, and then we have use this broad band antenna array in the array form I actually just want to mention to you people that this particular air element here that is a non-radiating adjust gap coupled antenna. I had done this work in my PhD thesis work.

So, I have finished at PhD work in 1983. So, what I am telling you is about 33-year-old story and in fact, we did published papers in 84 and 85 based on these configurations. And in my thesis during those days I had mentioned that these elements can be used in an array form to realize broadband micro strip antenna, but then the thing which I recommended in 1983 finally, I restarted the whole thing 30 years later and then we have now designed. So, here is another array same as this here and these are coupled with a u shaped you can say bent network here. So, that is a series feed.

We could still get impedance matching by feeding almost close to the edge over here and these are the simulated and measured results you can see that the results are fairly good agreement. And the bandwidth obtained here is from 5.535 to 5.84. And that is about 5 percent bandwidth we get it from this particular case here. You can also see that this is the gain plot. You can see that the gain variation over the bandwidth is relatively small and the maximum gain of the antenna array is about 13.4 dB. So, just to refresh this particular antenna as suggest these 3 element would give us gain of about somewhere between 8 to 9 dB. So, we could get a larger gain by using these elements. Of course, we have done only 3 of these broadband thing this concept can be extended to larger antenna array and there by realize broader bandwidth.

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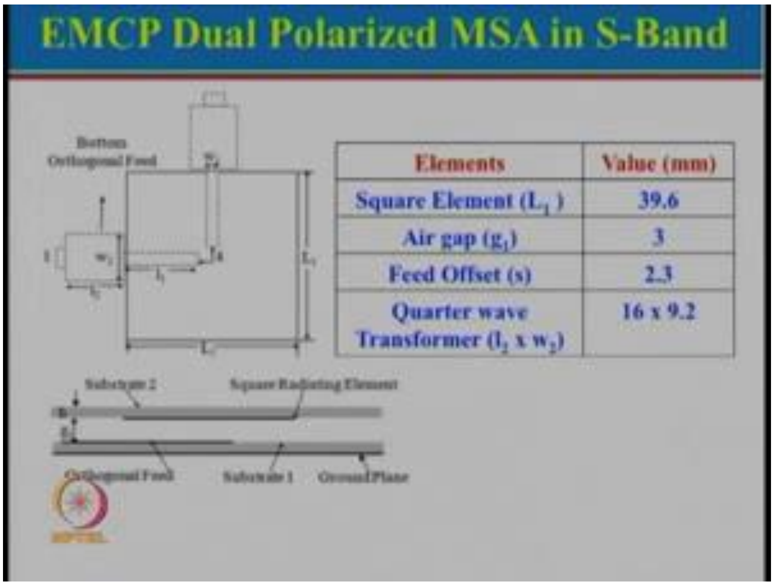

Now, will look at the another configuration. This is configuration is electro magnetically coupled dual polarized micro strip antenna. First will look at the concept here then will use this particular thing in an array form to realize larger gain. So, let me first tell what is the objective of this particular thing here. So, here the requirement was we wanted to have a broadband antenna, but we should have a very good isolation between the 2 orthogonal feed points. So, this is the configuration which we reported for the first time. So, what we have here. So, we have a one feed network over here let us just look into it what it is. So, this one if you look at here that is a micro strip line which is coupling with the top patch which is actually suspended in the air.

So, this is we have taken as a square radiating element, because we wanted orthogonal polarization at the same frequency, hence we took a square patch. And now this feed line here is getting electro magnetically coupled with this particular patch over here. Now here if we take this particular thing little down below here. So, then there will be coupling and if we take little bit above their coupling is slightly reduced, but the thing is bandwidth also increases. Since have a requirement was broadband we choose little larger air gap. And because of that what was happening then we coupled this here and because this gap was too much input impedance realize is relatively small. So, we used a quarter wave transformer to obtain 50 ohm matching here and then this one here is placed orthogonal to this when here it is important to have a small gap over here. So, that improves the isolation between the 2 orthogonal feed point over here.

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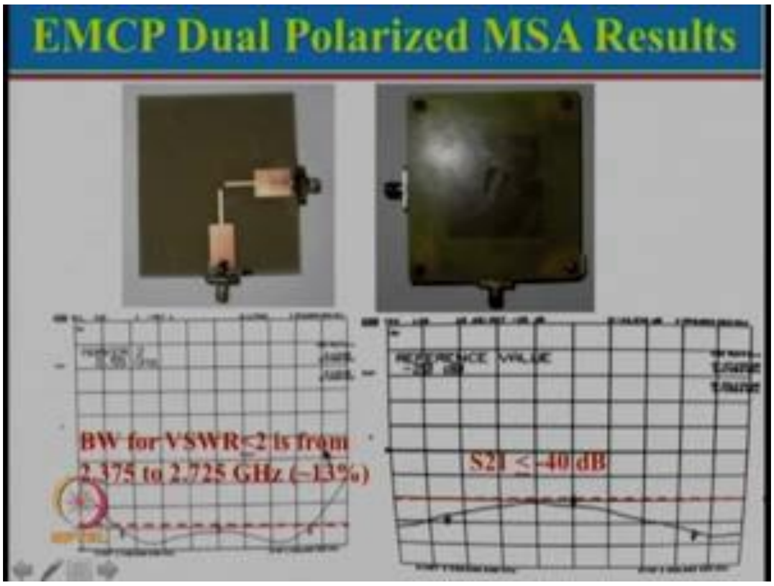

So, now, let us just see the results of this particular concept. So, here is the fabricated element. In fact, this particular thing we had designed it around 2.5 gigahertz frequency. So, you can actually see that this is the picture of the bottom layer where this feed line as well as quarter wave transformer is fabricated and they are 2 of them. And this is the complete assemble antenna; you can actually see little bit of this patch here because that patch is actually printed in the inverted suspended configuration. So, basically it is printed underneath this one here. So, when we take a picture from here, we are not able to see the patch clearly, but you can actually see little bit shade of that. And this particular antenna has been designed; you can actually see here that the bandwidth for VSWR less than 2 is almost 13 percent it is from 2.375 to 2.725. So, I just want to mention here.

So, this actually covers lot of different applications. So, for example, Wi-Fi application would be from 2.4 to 2.5 gigahertz which is covered by this antenna. Then lower band of y max that is from 2.5 to 2.7 gigahertz. So, even that has been covered by this particular configuration here. And now the beauty of this particular configuration is the isolation.

The isolation between these 2 and this is a measured value. So, the isolation over the bandwidth over here is less than minus 40 dB, when actually see that reference value is minus 20 which is over here minus 30 minus 40. So, that is the minus 40 dB line. You can actually see that in this range it is minus 40, but it is even getting below 50 dB. So, it is a very good isolation value. As I mentioned earlier our requirement was better than 30 dB here.

We achieved 40 dB. And any isolation better than 30 dB is considered could 40 dB is definitely very good, and I also we want to mention. So, this particular array concept you can actually give 2 different names. One is of course, orthogonally polarized micro strip antenna will talk about the array in the next line, but then it can also be actually nomenclature as memo antenna. So, basically multiple input multiple output. And for memo antenna it is very important that the isolation between the 2 feed should be very good. So, now, we will extend this concept to a relatively larger array. So, let me just go one by one.

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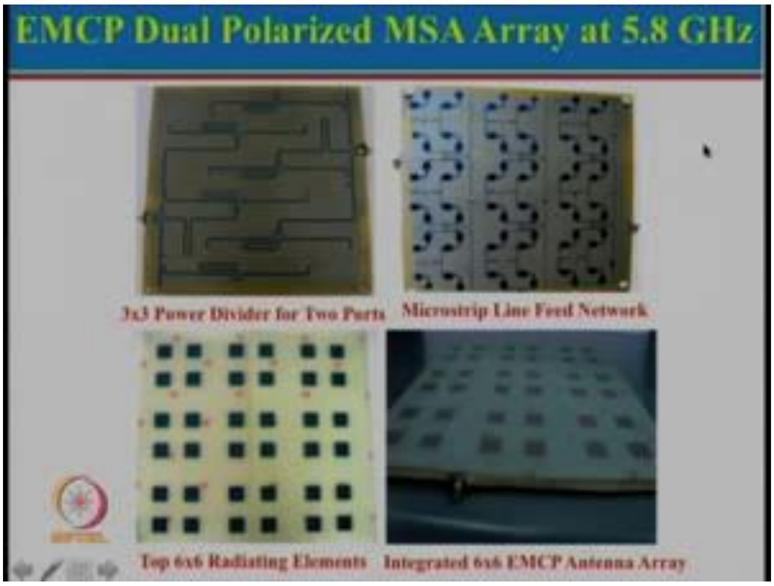

So, that single unit which we looked into it. So, now, that has been extended to 6 by 6 element array. And instead of designing the array at 2.45 this array is designed at 5.8 gigahertz, which is the y ma x higher band. And also this band has been declared free in many countries of the world. And it is of course, declared free in India also.

So, just to tell you, in India all these frequencies usage is decided by WPC wireless planning commission. And wireless planning commission comes under the umbrella of DOT which is department of telecommunication. So, you can go to their website and you can even download what are the frequencies used for what purpose and what are the free band. So, that will help you to design your next antenna or your next transceiver or transmitter receiver's system. So, now, coming back over here this 6 by 6 antenna array is use in the electro magnetically coupled configuration. So, just from here you let us come over here. You can actually see that this is the feed network, and you can actually see little bit carefully if you notice here that what we have here that these are the line here.

So, there will be patch will be setting on top of this here. So, you can see that there is a small line quarter wave transformer small line quarter wave transformer. So, on this one patch will be setting there. And then that is the same thing over here and then you can see that this is getting replicated here. And to all of these things we require a feed network. So, feed network is shown over here you can see that it is a fairly complicated feed network. And this network has been printed on the lower side of the ground plane. And plated through holes were connected from the bottom side to this particular feed network. So, that a proper power divider takes place. So, basically over here what we have actually done if you look into this here. So, there is a power divider network. So, since we have an array of 6 by 6. So, we have used a power divider first 3 by 1 power divider and then each 3-way power divider has been divided in to 2. So, that we get overall 6 by 6 power divider.

So, this is the complete assemble unit. And if you actually look in to here the total thickness is relatively small, you can actually see that the total thickness is still close to about SMA connector on array. So, now, let just see what are the measured results for this particular array.

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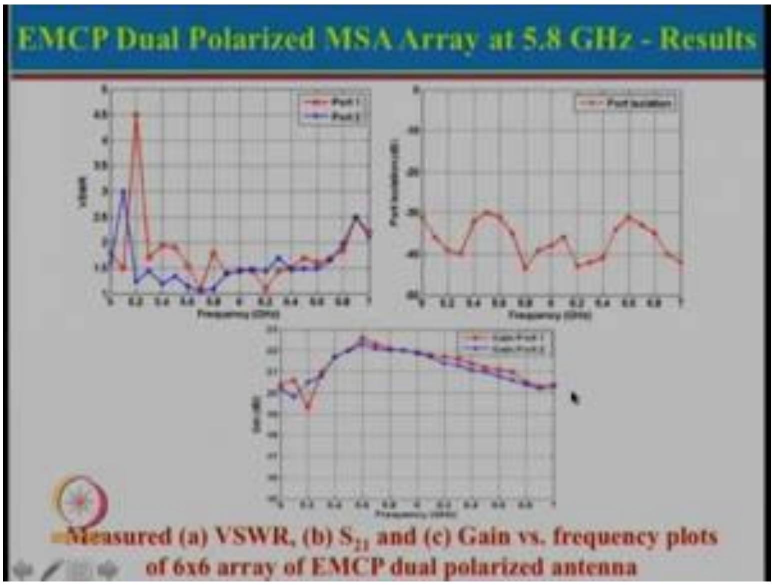

So, first let us just look at this is the VSWR. And since there are 2 ports are there port 1 and 2. Which are basically the 2 orthogonal port here. So, if you now we will see this is the VSWR 2 line. And if you look from the bandwidth even from here, this bandwidth is anyway from 5.3 gigahertz to almost 6.8 gigahertz. So, that is a bandwidth of about 1.5 gigahertz.

So, which is extremely high that gives us more than 25 percent bandwidth. So, that is the VSWR bandwidth. Let us just see isolation. As I mentioned the requirement was less than 30 dB isolation over the band, and you can see that we got a S 2 1 less than minus 30 dB or isolation better than 30 dB right from 5 to 7 gigahertz. And in between lot of places you can see the isolation is almost 35 to 40 dB below now. So, that is VSWR this is isolation, but these are not the only 2 important things we should also look at the gain and the pattern stability. So, here we can see that we got a gain of about 22 dB. And in this particular case one can see that if we just look at a 21 here. So, that is about here. So, the gain variation which is less than 1 dB and that is over a very large bandwidth of 1 gigahertz. So; that means, this is a good antenna array as such, which has a fairly uniform gain over the bandwidth and also which have not shown here.

But the radiation pattern, the radiation pattern also is fairly uniform over the entire bandwidth. Because once you know that if the gain is relatively constant; that means, the radiation pattern is also going to be relatively same here. And you can see that for very large range the gain is very close to about 22 dB. And in fact, this actually covers various band just to remind of a majority of the time people are looking at 5.8 gigahertz the bandwidth require could be 1.5 here or may be people looking in the 5.4 gigahertz band and that will also be you know covered in this particular array. So, one can actually see that this particular array is very useful to cover various band .and of course, you can modify this for any other frequency band also. So, now, let us just go to the next topic, which is phased array antenna. So, what is the concept of the phase array antenna?

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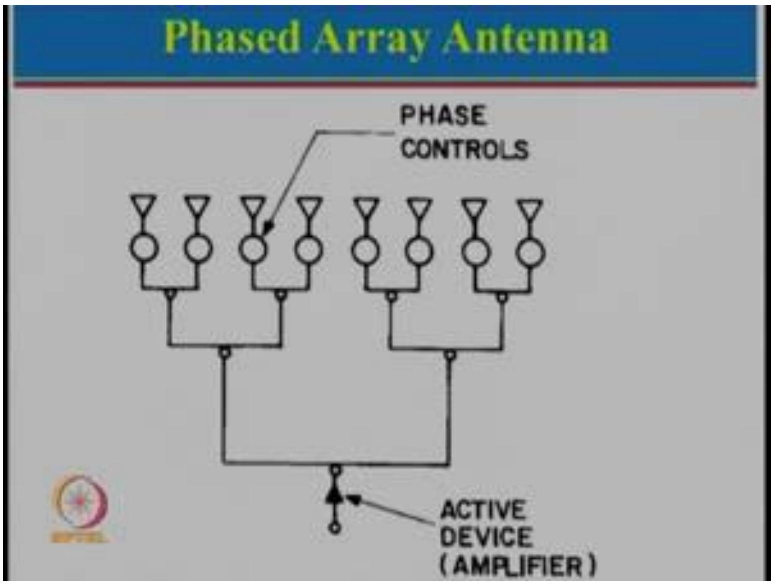

Now, again you will have to go back to the lecture which I talked about in the linear antenna array. For linear antenna array we had mentioned that if all the elements are fed with equal amplitude and phase then the beam is in the broad side direction; however, if we change the phases between the element then the beam can be scanned in this direction or this direction depending upon how you vary the phase. So, the phased array antenna is actually extension of that only. So, let us just see here we have linear arrays of 8 elements. So, what we have here we were 1 2 3 4 5 6 7 8 elements and first just look into here. So, these 8 elements are fed using a corporate feed here. So, this is the amplifier. So, from here it is divided into 2 then this is divided further into 2 then this is divided into 40. So, that is an 8 element array.

But in between what has been added these are the phase control values which are added over here. So, for example, if all the phases are 0 then it will be in the broad side direction, but suppose if the phase is if I start this as a reference. So, this is 0 this is minus 10 minus 20 minus 30 minus 40 minus 50 minus 60 then it will be having a beam shift like this, and that beam shift can be obtained.

Again from the array theory where we had seen that psi is equal to 2 pi d by lambda cause 5 plus delta. So, for desired angle 5 we can actually calculate what should be the value of delta, and then you can do the beam scanning. Now the only thing over here is that when you want to do something like this let us say now you want to change the beam from broad side to let us say 10 degrees then you want to shift to twentieth degree. Then all the phases to each element should vary accordingly. And that possess lot of problem for larger array imagine, if we have an 8 by 8 array. So, 8 by 8 array would require total 64 phase control even if one is reference it requires 63 phase shifted now think about if you have an array size of 32 by 32 which means 1024.

So, you need that many different phase control devices. So, these are the challenges. In fact, many a times what people do they actually use 2 by 2 sub array. So, that lesser number of phase shifts are require. And again there is a lot of research required for designing phase shifter. Phase shifters can be analogue phase shifter or digital phase shifter. In case of analogue phase shifter one of the device which can be uses may be a verector divot can be used which is given a voltage and by changing that verector divot correspondingly phase can be chained. Or in the case of digital majority of the time they use pin divot switches. So, by switching those pin divots you can actually change the shifts in steps. So, when you change the phases in step sometimes there is an error known as quantization error also comes into picture.

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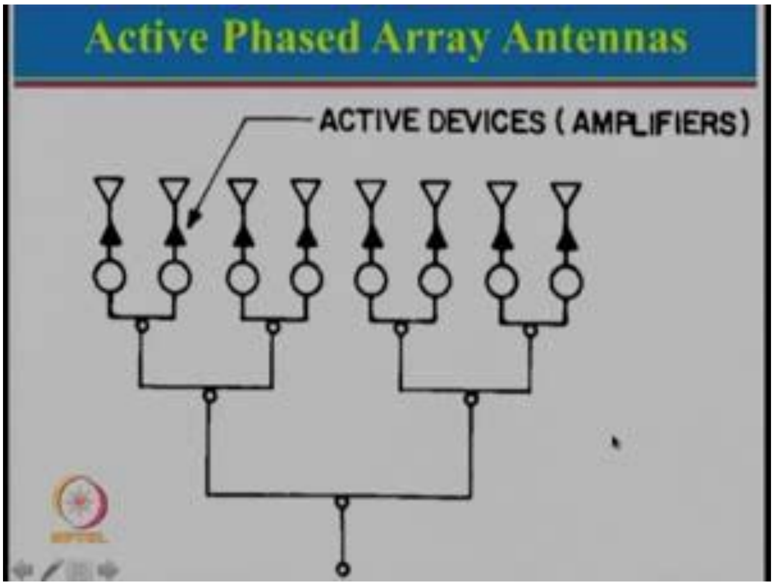

Now, this was a general phased array antenna. Now let me just talk about another thing it is an active phased array antenna. If you compare this with the previous example actually the additional thing what you see over here is this clock over here. And these are amplifier, but I will just mention little bit more about it. So, what is being done over here starting from here power is getting divided to various port, and then these amplifiers are used. And this is the actually a very important thing specially today when we want to transmit let us say very high power through the arrays. Now either we use a very high power single source or in this particulars what we can do, we can actually use relatively low power active sources here.

So, think about an application. Suppose we have a 32 by 32 element array. So, 32 by 32 means 1024. So, if you feed even one watt to each module that 1000 element really would mean 1 watt corresponds to 1 kilo watt of power. And if we have a 10-watt module to each one of them; that means, we are transmitting 10 kilo watt of solid state power amplifier now; however, there is a one additional thing I want to mention, the what you see over here is a one sided; that means, this configuration can be used for transmit purpose only, but if we want antennas also for receive purpose also.

So, in that case for receive purpose simple amplifier is actually replaced by t r module. Where t stands for transmit r stands for receive. So, transmit receive module. In fact, you can actually in a very simple thing. That transmit receive modules are nothing, but by directional amplifier with proper isolation between the 2. So, by using this particular think scheme here one can use multiple t r module and some of the t r modules may even consist these phase shifters also, and sometimes they may even consist attenuators also for amplitude controls so that we can control the side lobe level also. And in fact, many a times this active phase array are also used.

Suppose you are using for a particular application and there may be a jamming signal coming from some other direction. So, by doing a proper phase control, one can actually put a null in the direction of the jamming signal. So, there are many applications of antenna array. In fact, there are several books are there on phased array antenna. So, I want you to once you start working on these wonderful array techniques you will actually see that there are so many application, but yet there is a one major limitation I want to mention. Majority of the phase array antenna today are fairly expensive. So, majority of the time it is being used by the defense forces all over the world.

Right now commercial use of these phase array antenna is relatively very less. So, I hope that one day when all of these thing can be integrated and the cost of producing these arrays become less then these can be used for commercial use. So, for that you need to work on this come out with the novel design. There is a lot of research possible in this particular area.

So with that, in fact, I am going to conclude the micro strip antenna itself as well as array. So, we started with micro strip antenna array, then we looked at broad band micro strip antenna array, then we looked at the compact micro strip antenna, then we also looked at circularly polarized and even tunable dual band micro strip antenna. Then we talked about various types of micro strip antenna array.

So, we now conclude micro strip antenna, and in the next lecture we will talk about helical antennas, and will see how helical antennas can be use in different mode to realize different kind of radiation pattern. So, with that thank you very much and see you next time, bye.