Antennas

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Module - 08
Lecture – 36
Circularly Polarized MSA – III

Hello and welcome to today's lecture on circularly polarized microstrip antenna which is in continuation of the previous 2 lectures where we have been talking about circularly polarized microstrip antenna and we saw various techniques. So, we saw that we can feed the circularly patched polarized antenna, let us say that can be a square or it can be a circle and that can be fed at 2 orthogonal points with phase of one angle 0, one angle 90 degree then we also looked at various configurations which were actually using a single feed and these were variations of square patches or variation of circular patches or even variations of triangular patches then we also looked at the compact microstrip antenna.

And we also looked at one typical application which is for GPS where we really need a compact microstrip antenna then we had started discussing about the broadband microstrip antenna and I did mentioned that all the broadband techniques which we studied earlier and which are also covered in chapter 3, 4 and 5 of my book broadband microstrip antenna are also applicable for circularly polarized antenna.

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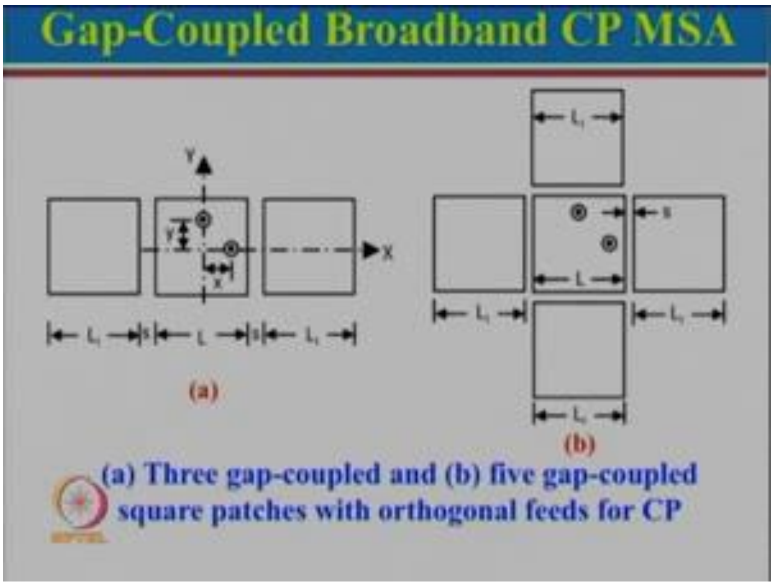

Let us start from there and will see some other broadband configurations also today. So, here we discussed about 3 gap coupled square patches because we need square patches here unlike in the earlier cases for broadband we could have length L and width, but here L is equal to w so that for orthogonal mode this also will Exide at the same frequency then instead of this particular configuration.

We can use this configuration where there are 5 patches which are gap coupled to the central patch and this gives us very large bandwidth; both AR bandwidth as well as VSWR bandwidth and we had also mentioned that if you want a larger AR bandwidth, sometimes a 3 dB 2 branch coupler may not be sufficient. So, we may have to use 3 dB 3 branch coupler or even 3 dB 4 branch coupler also then we had also looked into instead of using a the configuration which is in the planer nature that was gap coupled.

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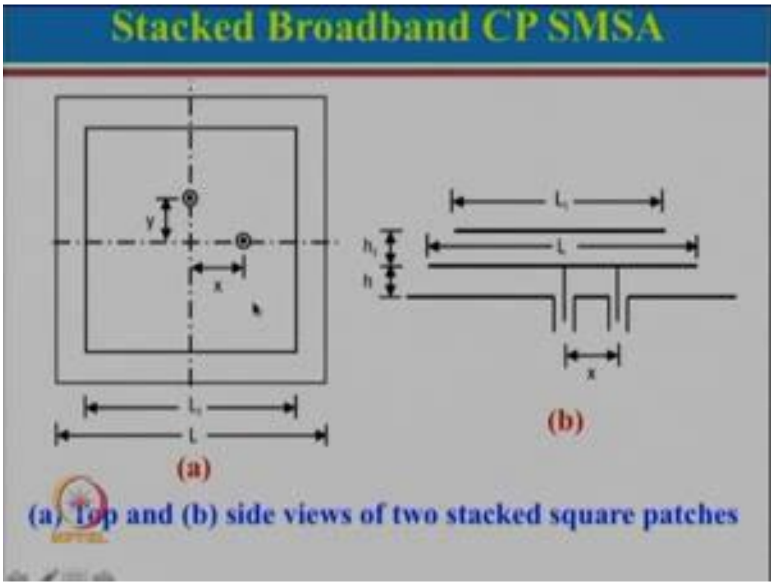

But we can also now use stacked configuration also. So, what we really have here? The difference compare to what we discussed in the broadband technique when we discussed about broadband stacked there L could be different then w.

But over here it has to be a square microstrip antenna and here the configuration which is shown is the bottom patch is fed at 2 orthogonal points and then there is a top patch. Now this configuration shown over here uses air here and air here and of course, we need to practically support these antennas and that can be supported right at the center over here. So, we can provide a central post to both the patches bottom and the top and that way we can suspend these things, but now suppose we also want to realize one angle 0, one angle 90 or one angle minus 90, there are 2 options are there, one is we can actually use an external 3 dB 2 branch coupler and the output of those 2 can be connected over here or if you want a same thing then that can be printed over here and the substrate here we can put a substrate here and then this can be again metallic plate with the central support over here or these can also be printed on the substrate either in the suspended configuration or in the inverted suspended configuration now.

This is the configuration and you can use the modification also instead of using a square patch you can also use circular patch you can also use triangular patches and so on and so forth and also instead of just using of gap coupled configuration like this which are covered in chapter 3 or instead of using stacked configuration which are covered in chapter 4, you can also use combination of all these things also for example, you can use 1 b 2 t configuration or 1 b 3 t configuration or 1 b 5 t configuration to realize even a much larger bandwidth.

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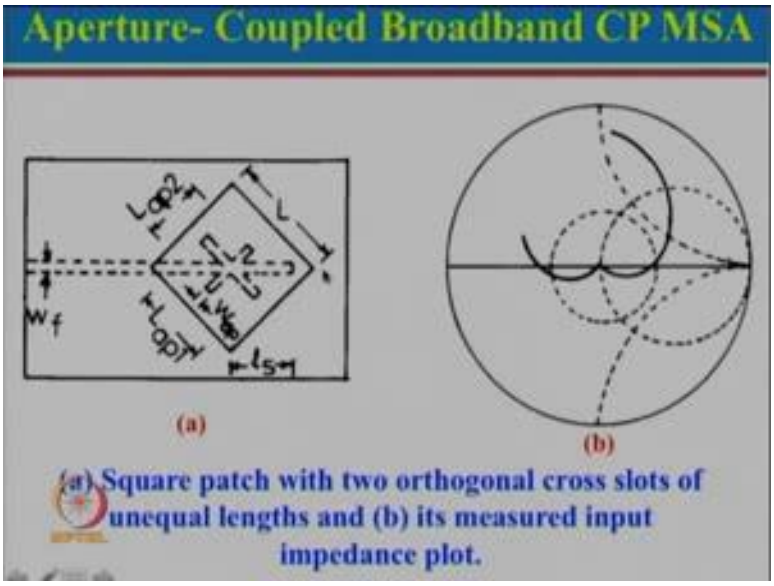

Now instead of using this, one can also think about another concept which is aperture coupled broadband circularly polarized microstrip antenna, let me first show the concept here. So, what is not obvious here; that is actually a multilayer antenna.

Underneath the multilayer, this is the microstrip line which is actually feeding the top patch which is in this particular case a square patch of length L through this slots which are cut in the ground plane which is sandwich between this microstrip line and this particular patch over here. So, you just need to imagine that there are 2 substrate. So, on the top side of the first substrate, the patches there underneath of that let us say there is a ground plane and we cut aperture slot over here and on the second substrate which is on the other side there is a microstrip line here. So, now, let just once we understand how it is drawn, now let just see this microstrip line will feed through these apertures which are cut over here and generally for maximum coupling what is dell this is an open end. So, generally this length is taken as lambda by 4.

That maximum coupling can take place to this particular patch through these slots here. Now to get circular polarization, we can actually say that here this is a square patch, but over here, the slots which are cut over here, these slots have a different length, you can see that this is a length of the aperture 2, this is the length of the aperture 1. So, these are the 2 different length and because these 2 lengths are different, so, the loading to this particular square patch will be different and hence it will give us a circular polarization, again there are lots of variations possible. So, one can actually have these L a p 2 can be equal to L a p 1 and then this can be a nearly square air is square patch with a notch and so on and so forth, but since this particular antenna is designed for broadband. So, here if we take, let us say nearly square then L 1 by L 2 ratio will not be close to 1.01.

But it may be close to 1.05 to 1.1 because we are travelling to realize broadband antenna. In fact, that is the purpose of the aperture coupled microstrip antenna and if we see the response of this particular antenna and we this is the smith chart plot here and I had mention to you that if you see a kink over here instead of a loop then we can say that would not be a very good actual ratio for this microstrip antenna. So, over here what we actually see that there is a kink in the smith chart plot. So, again that kink implies that there is a 1 mode getting excited and another mode as taken over and at that kink point, the 2 orthogonal modes are equal to each other, hence they give rise to good actual ratio.

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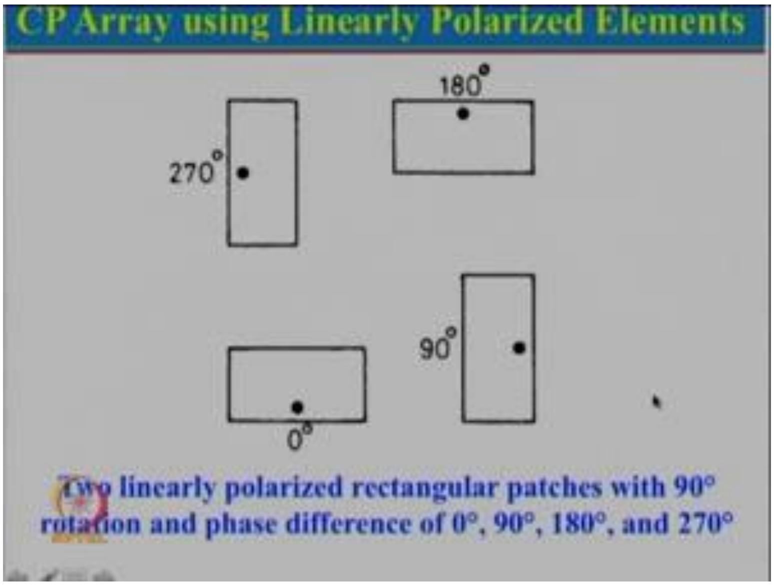

Now we will look at one vary another new interesting concept which actually was reported a few decades back and this is a very interesting concept even though I have shown for element over here, but first let me just talk about these 2 elements. So, now, what we see over here that here is a rectangular patch if feed is here so; that means, this particular polarization or you can say that if it will be in this particular plane now you think about this here the same thing is rotated by 90 degree. So, now, it is fed over here. So, in this particular case, we can say that this will be e plane. So, if you look at this is e plane in the horizontal this is a E plane in the vertical and the phase difference now between the 2 has been kept as 0 degree and 90 degree. So, now, from a far away point if you look at these 2 antenna.

What do we see? A faraway point is faraway and these are the 2 patches here. So, it actually see almost the same distance because this distance is very very small. So, really speaking, you can say that at a far away point amplitude received from these 2 will be actually same and since now these 2 are fed at one angle 0 and one angle 90 degree so; that means, these will give rise to circular polarization. So, this concept was earlier reported and that would was very good configuration and these are basically dominantly linearly polarized antenna because you can see here that compare to this length here, width is very different. Hence it is pre dominantly linearly polarized, this is also pre dominantly linearly polarized. Now this was the configuration which has been reported an at ACP by using only 2 patches, now what if we want to use these things to get higher gain.

If you want to get higher gain, what we need to do? We need to add more number of patches. So, then a few different configuration were reported earlier where this is 0 degree, this is 90 degree, this was also kept 0 degree and 90 degree. So, 0, 90 will make a pair, here 0, 90 will make a pair also and this is 90, 0 will make a pair. So, all these are pre making pairs of 0, 90 for a far away point; however, it was noticed that if this is fed at 0 degree and this is fed at 90 degree then the cross polar level was quite high and also VSWR bandwidth also not very good. So, then instead of feeding this at 0, it is actually fed at 180 degree. So, again you can see that this is rotated by 90 degree, another 90 degree, another 90 degree. So, there are 2 things are there one is the physical rotation of the patch and feed by 90 degree and additional thing is that the phases between these elements is also changed by 90 degree.

The combination of this particular thing here give very good circular polarization over very broad bandwidth then the concept came that why use linearly polarize antenna why not use something like a may be electrically polarized antenna and that is where this concept was reported. So, here is a concept first.

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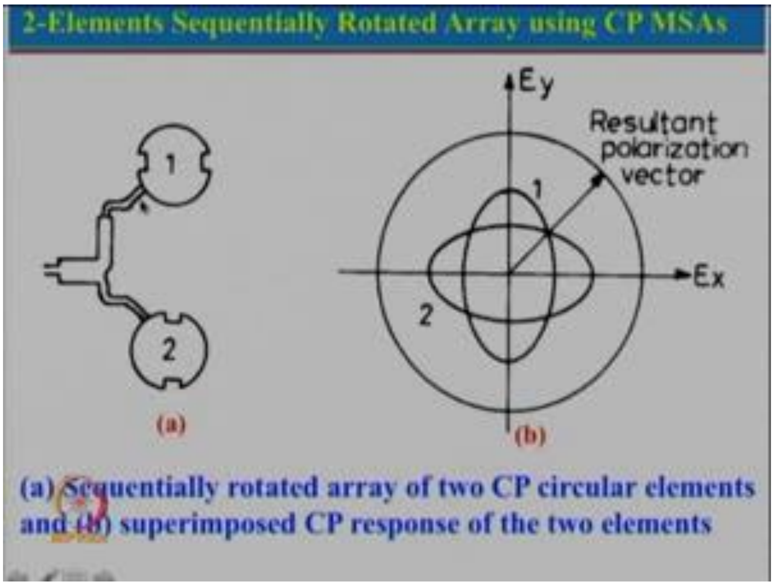

Let us just see what we have here. So, this we can see here is a circular patch with a notch and if you feed along the diagonal here, if you feed at the periphery here then we can see that this will be orthogonal to these 2 access and in that case it can give us a circular polarization, but since the feed is at the periphery input impedance will be very high and since it is a very high input impedance, a quarter wave transformer has been used to transform this high impedance to relatively lower value now.

If you look at number 1 and number 2, what you can see that this is rotated by 90 degree. So, now, these 2 patches are rotated by 90 degree and then there is additional thing this patches again since fed at periphery, it will have a very high impedance it is transformed to a lower impedance by using a quarter wave transformer. So, now, if you see that this particular patch has additional phase delay of lambda by 4 which gives rise to 90 degree phase delay, so if you see here from a reference point of view, if this is a reference as 0 degree, this reference will be minus 90 degree. So, now, let just imagine that we are operating this particular first antenna. So, now, we know that this length here is relatively larger than this length here so; that means, at lower frequency, this will be more dominant and then in between it will give circular and at higher frequency, this will be more dominant.

Let us just think about a lower frequency of point so at lower frequency, where this particular dimension is dominant. So, in that particular case, this will give us a vertically polarized pattern, but it will not be linearly polarized will be more like electrically polarized. So, at lower frequency of you see. So, this will be the pattern for one I will just repeat. So, here at lower frequency this is dominant. So, that is why vertical component is dominant and since some radiation will be agreeing because of this even though it is not fully resonant, but it is partly resonant because this dimension is relatively closer to this dimension. So, it will give us a somewhat electrical polarization now since at that particular point here this patches rotated by 90 degree. So, at lower frequency now that dominant will be this particular dimension.

That would give us the electrical circle like this here which will have a major access along this 1 here and minor along this here. So, dominant variation is in this direction, now just think about these 2 patterns are there and these 2 patterns are as 90 degree. So, what will be the resulted one resulted will be nothing, but Ex square plus Ey square. So, if you just look at the result here for this particular thing, we can actually see will get a perfect circular polarized antenna now plus just go in between. So, in between that frequency increases. So, in between frequency, frequency increases this is nothing, but a circularly polarized antenna this is also circularly polarized antenna which will give rise to circularly polarized component now at higher frequency when this is dominant. So, when this is dominant then for one this will be the field pattern and for 2 this will be the field pattern this will happen at higher frequency. So, again now if you take x square plus y square we will get a circularly polarized component.

That means, by using this particular configuration, we can actually get a circular polarization over broad bandwidth now instead of 2 element what if we want to use 4 elements if you want to use 4 element let us see what happen.

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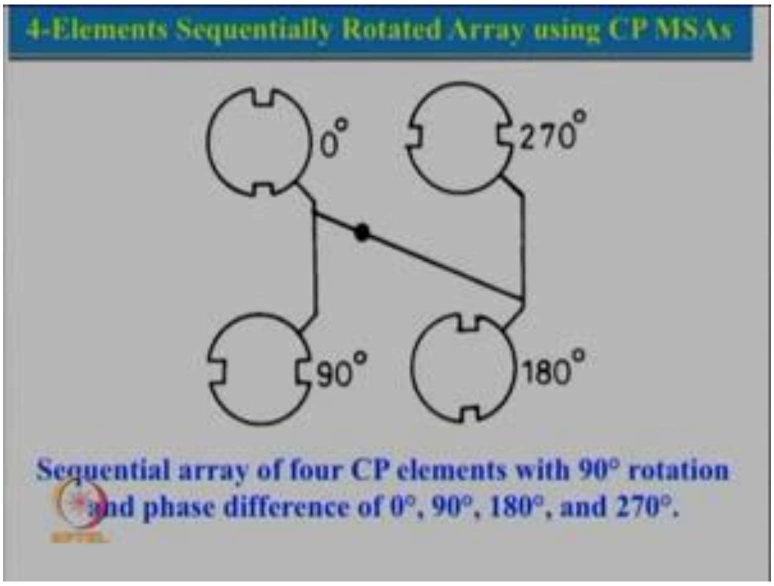

Here we have a one patch, let us start with here because that is difference here which is 0 degree. So, this is again similar to the previous case where it is a circular patch with a large here, I just want to mention here it is not necessary to use circular patch with notch we can use circular patch with strip you can use electrically ellipse also over here with the electricity ratio a by b you can use is instead of this nearly square also instead of that you can use square with notches or slit slots and so on and so forth. So, it is not important, it is just that it is shown this particular as an example, now this patch here this is 0 degree, it is rotated by 90 degree.

You can see that it is coming over here, this is again rotated by 90 degree and it is again rotated by 90 degree. So, now, this 1 here shows the feed point you can actually see how in a very very simple manner, one can actually obtain proper feed network. So, if you see here this particular length you assume that has to be common to all the other configuration. So, starting from here this plus this you consider this as a reference length let us say call it L 1. So, now, this part is common to this path here. So, what we need here this path plus this path of here which is common here this is for after that this should be lambda by 4. So, if that is lambda by 4, the path delay from here this will be if I say this is reference this will become 90 degree additional now if you look at this here.

This is symmetrical, this part is coming over here, this part is coming over here. So, we can say that this is that additional reference length here and this one will be additional lambda by 4 now additional hundred eighty degree phase difference is obtained.

You say that whatever is this length; this length has to be lambda by 2 plus this particular length and if this is lambda by 2 plus this length that would give us 180 degree additional phase shift. So, now, let us see what is happening. So, over here this is the reference length that is 0 degree let us has additional lambda by 4 length. So, it get 90 degree phase delay this has an additional you can say lambda by 2. So, that gives 180 degree additional phase delay, this is part of that reference and this one again gives additional 90 degree. So, that becomes 270 degree. So, now, this is the configuration. In fact, we have also realized this particular thing here and here also impedance matching also can be done in a very very simple and effective way since we are feeding along the periphery input impedance will be very high.

If you look at over here, so, one can actually use a thin microstrip line and over here thin microstrip line. So, this impedance and this impedance will come in parallel. So, that impedance will get reduced and again this impedance and this impedance will get in parallel that will get reduced. So, then from here and from here, the 2 impedances are getting in parallel. So, we can actually realize the 50 ohm matching over here. So, by careful design one can actually get a good impedance matching here also; however, if that is not possible we can always use a lambda by 4 transformer at all these points to get a proper matching over here now this gives us a fairly broadband configuration, but instead of showing the results of this here I am going to show you the results of the another configuration.

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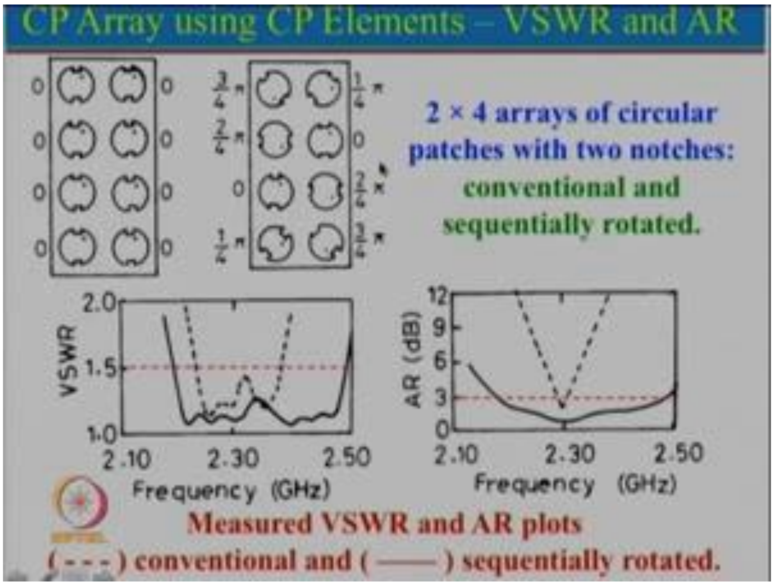

Now, this is the configuration where actually shows 2 by 4 arrays of circular patches with 2 notches and there are 2 configuration, one is conventional, another one is sequentially rotated. So, what is conventional if you see conventional array, what it has all the elements are similar and all the elements are being fed with the same phase and individual element is circularly polarized antenna. So, since individually these antennas are circularly polarized. So, that will give circular polarized antenna and since we are using eight of them it will give us higher gain, but over here instead of 8 element which are fed in the same phase here all these things are rotated. So, the concept over here is that instead of using for 2 patches, we had seen 0 degree, 90 degree for 4 patches; we saw 0 degree, 90 degree, 180, 270 and 360. So, now, if there are 8 patches, so what do you do? You divide that by 360 divided by 8, so now, each individual is rotated by 45 degree.

0, 45 then 90 and then keep on putting together and get the phases. So, if you see here. So, you can see here, this is 0 pi by 4 is nothing, but pi is 180. So, that will give us 45 degree and this is what the rotation has been done over here in this particular case. So, now, if you look at the results of these 2, so, first lecture and these you can see here, these are the measured VSWR and AR plot. So, if you look into here, the VSWR is really very good, you can see it is the line which I have drawn is at 1.5. So, you can actually see from 2.1 to 2.5 frequency response, we can see that this is the plot for the conventional antenna. So, which we know that it generally gives us a nearly you know you can say that nearly circular patch with notch the all are single feed they give larger VSWR bandwidth, but the problem with these antenna is they have a relatively smaller AR bandwidth, you can actually see that this is the dotted line which have shown here for AR equal to 3, you can see that the band width is relatively very small.

So, even though VSWR bandwidth is so large, but it is not at all a useful bandwidth. So, really speaking for circularly polarized antenna, this is the only useful bandwidth. So, all of this VSWR less than 1.5 is not at all useful; however, when we use these sequentially rotated antenna, in that case you can see that the actual ratio bandwidth is very very large and you can just think about that concept which we mentioned to you, I will just go back. So, if we have a multiple number of elements so what happens? This is just for 2 element will have a one response and that will with another respond now you think about multiple elements which are acts 0, 45, 90. So, will have a one response like this, another response will be like this here, third response will be like this here then there will be another response.

And if you take combination of all these will get a really good circularly polarized response. So, that is what is happening and a good circular polarization response is indicated by good actual ratio you can see that this actual ratio is fairly large and over here also one can see VSWR less than 1.5 bandwidth is really very very large. So, why VSWR bandwidth is large again I had mention to you when we were discussing about this concept here. So, if this is 90, this is 180, 270. So, these 2 the reflected VSWR from here at the reflected VSWR or you can say reflected reflection coefficient from here there will be out of phase. So, there will try to cancel each other and hence we get a very broad VSWR bandwidth also. So, you can see that this in the entire range they are effective actually see over this bandwidth VSWR maybe even less than 1.3 or 1.25 also, but we get a fairly large actual ratio bandwidth.

It is basically very good circularly polarized antenna and then you really have to start thinking if sequentially rotated antenna is good from VSWR point of view, it is good from actual ratio point of view then why you ever use this particular configuration, now see in fact, I always believe that you know nothing can have all the advantages, anything you take, it will have lot of advantages, it may have some disadvantages also, I mean think about let us say if I take a Maruti car or I take Mercedes car. So, Mercedes car definitely looks very nice it has a very good performance and all that, but then there is a disadvantage associated with that and what is the disadvantage? The price is very high and maintenance is also very high, but otherwise it has a brand, it has everything, but; however, both Mercedes as well as Maruti; they have their share of market now similarly over here when we actually looked into this sequential rotated array.

I went through this lot of paper at all the papers were only talking about fantastic VSWR bandwidth fantastic actual ratio bandwidth and I was trying to figure out then what is the disadvantage why I should ever use a conventional this thing I did not really find much of that answer, but in general what I finding many a time the publish papers always talk about the advantages of that particular thing. So, if you give let us say this particular antenna they only talk about the advantages only and sometimes I really feel that have a become a sales people are we really a scientific community a scientific community should always say what are the pros and cons what are the advantages and disadvantages, but I was very disappointed I only sort advantages. So, what are the disadvantage that is what a sales person will tell you if a sales person is trying to sell a car or anything or furniture that will only keep talking about the advantages plus his point.

Because the sales person has to sell the product, but a researcher has to give the information to the people and the scientific community should not only talk about advantages, but talk about disadvantages. So, then we have to study we did study with simulated these things with the experiments and now I want to tell you what is the disadvantage of this particular configuration. So, this particular configuration has relatively lesser gain compared to this particular array here because here what is happening all the elements are radiating together. So, the contribution towards the plot side direction in this narrow bandwidth all of them radiating in a similar fashion.

They give rise to better gain over here what is happening, this one will give us let us say this polarization this will give at 45 degrees, this will give at another angle. So, what is happening? We are actually seeing the contribution like this here. So, here more contribution from here, but for this particular patch there is a relatively lesser contribution right whereas, had it been all same then all the circularly polarized component will be giving the similar performance. So, here the contribution from one patches more, but contribution from this patches relatively less and that is why the gain of the sequentially rotated array in general is less than the gain of the normal conventional antenna array. So, if your application demands high gain then better use conventional, but if you are application require larger actual ratio bandwidth larger VSWR bandwidth and you can compromise little bit on gain then please use sequentially rotated microstrip antenna and since we talked about all these arrays.

We now need to know also; how do we feed all these arrays? So, in the next lecture, I will actually talk about microstrip antenna arrays; will talk about how to feed different elements, what are the different feeding techniques and how we can optimize the performance for different configuration.

So, just to summarize today, so today we talked about broadband circularly polarized microstrip antenna which can be realized by using 2 feed or we can use the configuration of gap coupled, we can actually build the array in the planer or we can build the antenna in the vertical plane which is a stacked or we can do both the things and thereby we can realize broadband circularly polarized microstrip antenna and those 2 feed things if you actually think about they to give us broadband width as well as they give us broad actual ratio bandwidth then we looked at this sequentially rotated array and we did noticed that actual ratio bandwidth is fantastic VSWR bandwidth is fantastic, but there is a compromise of slightly reduced gain that is acceptable absolutely fine, but in the next lecture, will talk about microstrip antenna arrays and arrays and arrays.

Thank you very much, will see you in the next lecture, bye.