Antennas
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Module - 06
Lecture – 28
Broadband MSA-V

Hello and welcome to today's lecture on microstrip antennas. In the last few lectures we had looked at several techniques to increase the bandwidth of the microstrip antenna and these are you can actually increase the thickness of the substrate or reduce the dielectric consent of the substrate or we can actually use multiple patches. So, there is a one patch here and we put patches on one side or another side or on all the 4 side or we can use circular patches. So, these were the configurations where we added multiple resonators in the horizontal plain.

Then in the previous lecture, we saw that you can put antennas in the vertical direction also to increase the bandwidth of the antenna and for the vertical direction, we saw 2 different configurations. So, one was electromagnetically coupled and the other one was aperture coupled. So, today we will look at some other configurations where we use antennas in the horizontal as well as in the vertical and thereby we can obtain much larger bandwidth then by individually using those configurations.

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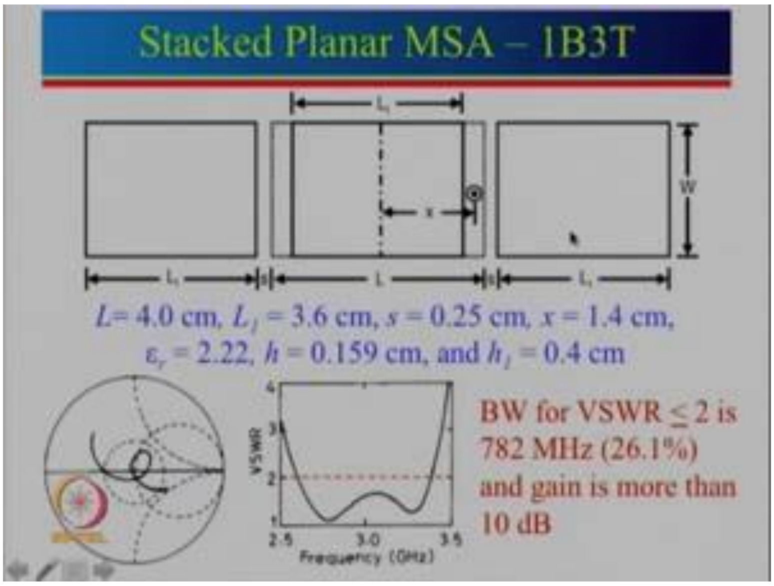

Let us start with the start planar microstrip antenna. So, what really it implies that patches are stacked also and the patches are planar also and the symbol I just want to tell, so what the symbol means that is a 1 B is for 1 bottom patch and 3 top patches.

Here you can actually see this is the dotted configuration here; this one and that is a patch at the bottom substrate and then we have taken 3 patches on the top substrate and we have taken the 3 patches to be identical. So, the top patches lens are same L 1 L 1 L 1 so that the resonate at the same frequency. So, again here just to mention now, so length of the bottom patch is taken as 4 centimetre, the top patches have a length equal to 3.6 centimetre, the gap is taken as 0.25 centimetre, feed point is very close to the edge; you can see that this is a 4 centimetre, this is actually very close to the edge. So, we have used that and epsilon r for the bottom substrate is taken as 2.22, 0.159 and these 3 patches are in the air and for that the height is taken as 0.4 centimetre.

Now, these things have been optimized, so the optimized; you can see that the response is that for this particular configuration, the loop is right within the VSWR equal to 2 circle and one can see that the response here. So, we have this particular portion which is within VSWR equal to 2 line and we get a bandwidth of about 782 megahertz which is 26.1 percent. Now this bandwidth is much larger than we go; the bandwidth by using only planar configuration or by using only stacked configuration and since now the total aperture size has increased, so gain has also increased and in this case, we are getting a gain of approximately 10 dB and the beauty of this is that the variation over the bandwidth is relatively very small and just to tell you, so we already have seen what are the effects of the various dimension, but just refresh those things. So, suppose if we change the length L 1, so if the length L 1 is increased. So, what will happen? Its resonance frequency will decrease. So, this loop would have shifted to this location.

Suppose if these lengths were reduced then its frequency will increase then the loop will be not forming here, but it will be forming somewhere else over here, similarly if we change the value of h 1, suppose we increase h 1 further, what will happen? If h 1 is increased further, coupling between the bottom patch and the top patch will reduce and then the loop size can be reduced. So in fact, that may be desired, sometime suppose we need a VSWR less than 1.5 over bandwidth. So, what we can do? We can increase h 1 and if we increase h 1 coupling will reduce and if coupling is reduced, this loop size will reduce and then this variation will be within the VSWR; less than 1.5.

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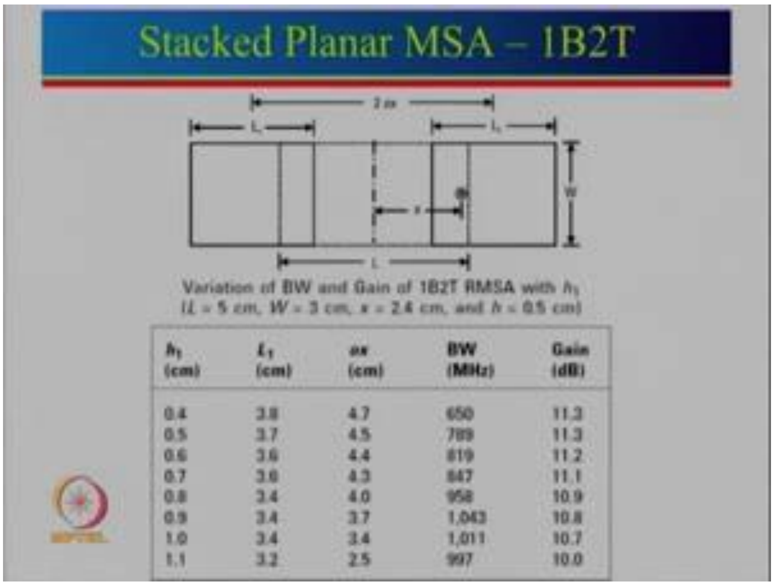

h_1 (cm)	L_1 (cm)	sx (cm)	BW (MHz)	Gain (dB)
0.4	3.8	4.7	650	11.3
0.5	3.7	4.5	789	11.3
0.6	3.6	4.4	819	11.2
0.7	3.6	4.3	847	11.1
0.8	3.4	4.0	958	10.9
0.9	3.4	3.7	1,043	10.8
1.0	3.4	3.4	1,011	10.7
1.1	3.2	2.5	997	10.0

Let us just now, look at another configuration which is 1B2T; that means, there is a 1 patch at the bottom and there are 2 patches on the top, this configuration; we propose for the first time. In fact, while I was writing this book on microstrip antenna, we thought of this configuration and we worked on this. So, here just to tell you, what we have done, so there is a 1 patch at the bottom which is shown as a dotted line here and the length of this patch is taken as 5 centimetre, we have taken a slightly lesser W; the only reason why we took slightly lesser W so that we can get a proper impedance matching because now this configuration gives very large bandwidth. In fact, by increasing W, we can still get more larger bandwidth, but there was a problem was that we could not do a proper impedance matching for larger W, hence smaller W has been taken here.

You can see that the feed point is almost close to the edge because length is 5 centimetre; half of length will be 2.5. So, this is up to here is 2.5 and the feed point is at 2.4 centimetre. So, if we had increased the width more than this impedance matching with 50 ohm was not possible of course, that matching can also be done by using external quarter wave transformer or maybe a multiple stage transformer to do the impedance matching, but here we do not need any external device or the network to do the impedance matching.

Now, the 2 top patches are here, we have taken these 2 top patches identical which is given by this length over here and then the separation between the 2 patches is given by

2 ox, but from the centre of the bottom patch, this separation will be about ox. Now what we had done here? Let us see. So, the bottom patch is at h equal to 0.5 centimetre; now to realise broadband width, we have taken everything in the air. So, that epsilon r will be equal to 1 which gives us larger bandwidth.

Now, what we have shown here? We actually ran several cases where the height of the top patch h 1 is changed. So, this height h 1 is from the bottom patch. So, the bottom patch is at height 0.5 and now the top patches are at additional height of h 1. So, you can say that the total height of this entire antenna will be 0.5 plus h 1. So, now, what we are showing here? So, different values of h 1 are taken. So, which vary from 0.4 to 1.1, now you can see that correspondingly, L 1 has to be reduced, why because as h 1 increases. So, fringing field will also increase and if the fringing fields increase, the total length will increase. So, to maintain the resonance frequency of the top patches close to the bottom patch resonance frequency, so what we need to do? If h is increasing; that means, fringing fields will increase that will increase the total effective length.

L 1 is reduced slightly so that the total effective length gives us a resonance frequency which is relatively closer to the resonance frequency of the bottom patch. Now ox had to be also varied, why we had to change ox because when you increase the height; that means, what happens if we increase the height? Coupling will reduce. So, to increase the coupling, these patches on the top were brought closer to the central patch which is fed in the bottom.

Bottom patch is radiating and coupling will happen through the fringing field. So, if the patches are far away, coupling will be less. So, we had to bring these top patches closer to each other. So, that the separation is reduced. Now 1 can see the bandwidth, so, since h 1 is 0.4, 0.5; we are increasing the top patches thickness is getting increased. So, we can see that the bandwidth is increasing from 650 and we cross the barrier of 1 gigahertz also, but after that the bandwidth starts reducing, the reason for that is that the coupling is very weak with this particular height. So, the loop size is remains is becomes very very small and that is why bandwidth obtained is not so good. So, this is not the value which to be used effectively in the application.

Now, let us see what happens to the gain. So, one can see that the gain is about 11.3 dB which is actually decreasing. So, why gain is reducing? The reason why gain is reducing because this ox is reducing and ox means the separations you think about the top 2 patches like array of 2 elements and since these 2 are identical, we can apply the array theory. So, we will know that. So, there will be bottom patch radiating the top 2 patches are radiating and these 2 top patches, this is the separation between the arrays of these 2 elements and if the separation is reduced; that means, the total aperture will reduce and that is why gain will reduce. So, I do not recommend that you use this particular height here because here gain is also much lesser. So, depending up on the requirement, how much bandwidth is required? 650 to 1 and correspondingly you can see the gain reducing slightly, but the reduction is not very significant.

Depending up on the application, one can use any of these configurations. So, this is really a very nice interesting configuration where we can get a larger gain also and we can get a very large bandwidth and there are only one small thing is there, here everything has been taken in the air. So, we need to provide the supporting structure. So, that precaution one has to do it. So, do not take these results as it is, you need to modify these things because you need to provide proper supporting structure; then only it will be a real practical antenna.

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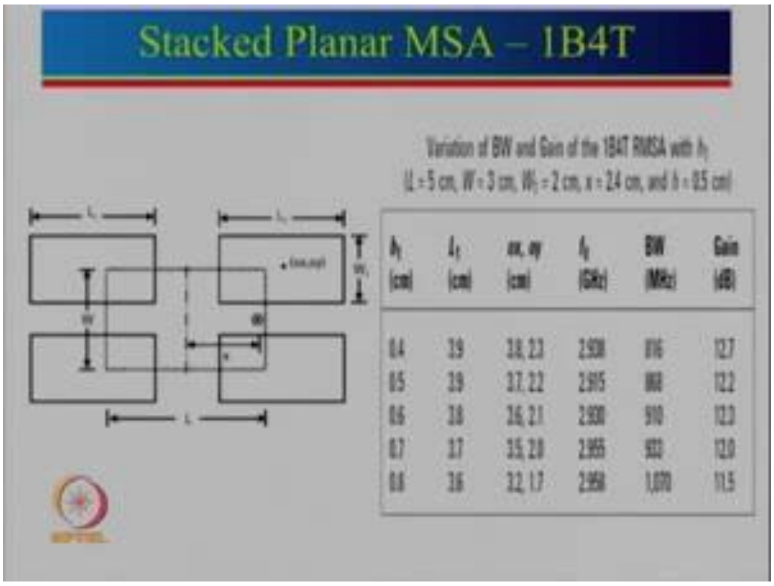

The next, we will look into the configuration which is again stacked planar MSA, but now this configuration is 1B4T; that means, there is a 1 patch at the bottom and there are 4 patches on the top. Now as in the previous case, we took L equal to 5 centimetre, W equal to 3 centimetre and for the bottom patch, we took as before h equal to 0.5 centimetre again, the feed point is very close to 24 centimetre.

Now, here what we have done for the top patches? All the top patches are identical, but we have taken much smaller W for the top patches and I will tell you the reason also. See now, the top patch is being fed along the diagonal. So, if this width is comparable to this length here then what will happen? Orthogonal modes will start getting excited. We could have taken slightly larger W also which will give us slightly larger gain also, but we chose slightly smaller again. So, that because see this configuration gives us very large bandwidth and since the configuration has a very large bandwidth. So, we had to take a much smaller W. So, that in the entire bandwidth of the antenna, this never ever becomes a resonant co so that orthogonal modes do not get excited.

Again as in the previous case we took multiple heights. So, h 1 0.4, 0.5, 0.6 then correspondingly as the height is increasing, the patch dimensions had to be reduced slightly. So, that it accounts for the increase fringing field because of the increase in h again concept is so that the resonance frequency of the top patches remain closed. The resonance frequency of the bottom patch now in this case, we had to change the offset both in x direction and y direction.

What are these off sets here? So, we can see that if we just look at the point here, this is ox oy. So, that is the origin. So, ox oy, so if ox oy is large; that means, there is a larger offset and if ox oy is less, you can see here; that means, these off sets are reduced. So, basically now for smaller h 1, we needed a larger offset, but as we increase the value of h, coupling from the bottom patch to the top patch reduced. So, to increase the coupling, these patches were brought closer to the central patch here. So, this is the values of ox and oy. Now correspondingly, we try to keep the resonance frequency which is close to 3 gigahertz or here 2 .93 to 2.95 or 2.915. So, it is between 2.923 that was the idea. So, that we can compare properly that what is the effect of all these things and over here, we can see that the bandwidth is 800 megahertz to almost close to 1000 megahertz or 1 gigahertz.

Now, one can see the gain. So, gain here is about 12.7 and that is reducing to value of 11.5, again why gain is reducing because gain is reducing because the offset is reduced, offset is reduced means you can now think about 1, 2, 3, 4. So, it is acting like a 2 by 2 antenna array. So, if the ox is further away; that means, the total aperture will be large id, the total aperture is large, gain will be more and if the offset is reduced; that means, all the patches are coming closer to the central patch; that means, the total aperture size will reduce. So, gain is reduced. So, you can see that except for this one here, for all these cases gain is more than 12 dB and one can get a very large bandwidth, you can see that this bandwidth let us say this is approximately 3 and that is about 930 so that is about 30 percent bandwidth roughly, we can get by using this particular configuration.

Again a word of caution; we have taken in the simulation air for bottom patch and air for the top batches; we cannot have these batches suspended in air. So, when we do a proper practical implementation of this, the bottom patch has to be supported, all the top 4 patches have to be supported, there are practical issues in simulating and realising this antennas. So, you please take care of that when you are doing a real practical design, but it does give very large bandwidth and also gives us a decent gain of around 12 dB.

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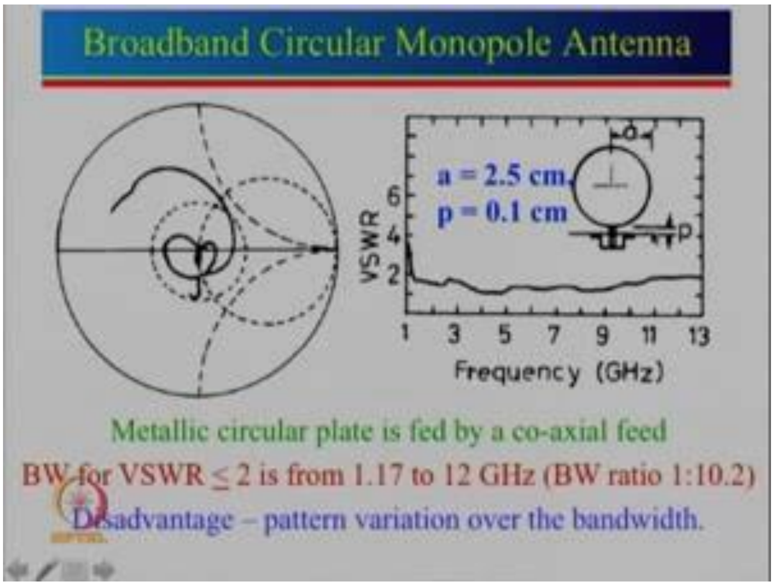

Let just now look at the another configuration, now this configuration may look familiar to you when we discussed about broadband monopole antenna, I had shown you this particular configuration and we had also shown you that it gives a very large bandwidth. So, now, you might wonder why I am showing this particular configuration one more time and we are talking about microstrip antenna, why did I bring the picture of a monopole antenna here? The reason I want to tell you that we explained this particular thing using the concept of microstrip antenna.

I just want to go almost nearly 2 decades back, this configuration was reported in one of the conference paper and it actually reported a very large bandwidth. Now we did not really understand what is going on. So, what we did? We actually did lot of experimental work. So, we took the circular patch of different dimension and we actually found out that it gives larger bandwidth that instead of circular, we used electrical monopole which was of 1.1, 1.2, 1.3 electricity ratio. So, we studied, what is the bandwidth of those antenna then we used square patches, we used rectangular patches, we used hexagonal patches we used triangular patches and so on.

It was very difficult still to understand and explain; why we are getting this large bandwidth? So, then we thought of an alternate things. So, we actually thought about is that see this antenna; think from a microstrip antenna point of view. So, if we look this antenna from a microstrip point of view. So, think about this is a monopole antenna with a ground plane, but now we will explain this entire thing from a microstrip antenna point of view. So, let us say, we have a circular patch and there is a ground plane. So, for this circular patch if I want to increase the bandwidth, what we need to do? Instead of using a substrate of finite epsilon, we use air. So, if epsilon r is equal to 1 that will give us larger bandwidth.

Now if we use thick air substrate or you can say that if it is height is increased. So, what will happen? Bandwidth will increase, but we have noticed that if we have a ground plane here and we have a patch here then we use a coaxial field. So, what happens as you keep on increasing this thickness from here to here? The probe inductance starts increasing and that probe inductance then gives inductive effect and the entire loop shifting towards the inductive region. So, then we thought of another way that there is a circular patch here, we have a ground plane. So, why not we add another ground plane on this side? So, like a L shaped ground plane and now if we feed from the side. So, if we feed from the side then the probe length will be relatively small and now we have a 1 ground plane like this another ground plane. So, now, you think about increasing this spacing here so, if we increase this spacing, but the probe is being fed from this side.

Probe inductance is not increasing significantly, but this height is increasing. So, it keeps on giving larger bandwidth and now if you remove it so what will happen? It will give a very broad bandwidth. Now why circular patch gives better bandwidth compared to the rectangular patches? The reason for that is rectangular patch will have the next higher mode which will be given by let us say 1, 0 then 2, 0, 3, 0. So, 2, 0 will happen at double the frequency whereas, in case of circular microstrip antenna, the modes are given by K nm and the nm for the fundamental mode is 1.84118 which is for T M 11 mode and then the next mode which is actually equal to given by 3.054.

If you take the ratio between 3.054 and 1.844, it is approximately equal to 1.6. So, now, think about that multiple modes are getting excited. So, now, if we have a 1 mode which is exciting at a lower frequency and that will be corresponding to 1.84 then we have another mode which is coming and that is exciting corresponding to K nm equal to 3.054, but now if we start increasing the bandwidth of the individual mode and that will happen if we take epsilon r equal to 1 and a larger h. So, what happens? Then after some time, the band of this and the band of this they start overlapping. So, really speaking what happened? So, corresponding to 1.8411 K nm value there is a one resonance guard then the other mode comes. So, then again another response, then another response, then another higher mode and then we get a larger bandwidth. So, that is the simple explanation for this circular monopole antenna.

Basically what happens? You can explain it using the concept of microstrip antenna that multiple modes are getting excited and because multiple modes are getting excited, radiation pattern is not uniform over the bandwidth. In fact, we did many other experiments also. So, we had of this monopole antenna, we even put a reflector here also just as I said. So, there is a ground plane and a reflector we kept on changing the dimension and we could get the more gain in this particular direction also. So, many different things were studied at that time. So, one can see that this circular monopole antenna is really nothing, but can be explained very conveniently using the concept of the microstrip antenna. So, just to repeat quickly, so what we really have here? Think of this patch, there is a ground plane on the backside that will look like a microstrip antenna and then we feed it from the side and if you remove this particular backside thing that microstrip antenna then becomes a monopole antenna.

In this particular case, we had used a metallic circular plate which is fed by the coaxial probe and we really got a very large bandwidth, right from 1.172 12 gigahertz and this is the bandwidth ratio which we obtained. Now the disadvantage of this is that there is a pattern variation over the bandwidth so; however, several other configurations have been reported based on this particular configuration. In fact, we published this paper in (Refer Time: 24:10) and this paper had been used very widely by several researcher and then this particular geometry which is more like a 3 dimensional configuration you can think about this is a planar disk, but then this is ground plane which is perpendicular to it. So, later on, lot of configurations came where they actually replaced this 3-D dimension into a 2 dimensional planar configuration. So, let me show you just one variation of that. So, you can actually see even though I am showing a triangular configuration here.

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Now, here people used a circular configuration. So, circular patch was printed on one side of the substrate and ground plane was printed on the other side of the sub straight. So, you can see that now ground plane is not perpendicular to the radiating patch, but it is actually in the plain. So, in this case you can just imagine that this is a let us say triangular patch and there will be fringing fields which are getting to the back to the ground plane over here.

So, now, in this particular case, again lots of variations have taken place. So, people have used circular patches people have used semi circle people have used triangular even a parabolic shape has been used here and another shape is used here. There are lots of papers are there which are instead of using a rectangular ground plane they have used a curve ground plane also. So, there are several configurations which have been reported using this simplified monopole concept and again you will think why I am teaching monopole in the topic of microstrip antenna I will give you that reason also, but let just complete this part here.

In this case also, one can actually get a fairly broad bandwidth depending upon the configuration we chose, this one here because the pattern variation of this configuration over the desired bandwidth which. In fact, this particular configuration, we had designed it for RF harvesting. So, we can see that there is a mobile phone over here which makes a call RF, this is the RF harvesting circuit this is the antenna and this is the configuration which is nothing but a rectifier circuit and output of this is connected to the multi meter. This is in the open circuit configuration. So, you can actually see that when a phone rings, you can actually generate 6.74 volt and in fact, we have also put the load across these 2 point also. So, depending upon the load value, suppose let us say if you put a load of say 4.3 k, this voltage drop to approximately about 4 to 4.5 volt. So, you can see that typically 5 to 7 milli watt powers can be generated through this particular RF harvesting thing. In fact, we have used array of this also to get the larger voltage.

Now this configuration, now recently we have used for ultra broad band microstrip antenna configuration, what we did it is we put a ground plane behind this. So, by putting a ground plane so this is one ground plane now you think about another ground plane or in fact, let me call that as a another metallic reflector was placed behind this here. Now the general concept is that you put that metallic reflector behind at a spacing of lambda by 4, but I would just like to mention that should be a lambda by 4 spacing at the maximum desired frequency. So, corresponding to maximum desired frequency.

This spacing between the radiating monopole you put this metallic plate over here. So, now, what happens because of this metallic plate the radiation will go back it will reflect back to this? So, this becomes now unidirectional antenna. So, it is not really strictly microstrip antenna you can think about this as a monopole antenna with a reflector which gives a unidirectional thing, but again we can still explain in the form of the microstrip antenna concept also and here just to mention. So, when you design this kind of the antenna, you can simulate the entire configuration with the metallic plate and the spacing at lower frequency will not be lambda by 4 it will be much lesser than lambda by 4.

These antennas we could optimise to give broad bandwidth right from nine hundred mega hertz to eighteen hundred mega hertz. So, that is a very large bandwidth using the concept of the monopole with reflector or you can say it is somewhat similar to microstrip antenna as far as the pattern is concerned, it is radiating pattern in the broadside direction. So, today we have looked into various broadband configurations. So, we can increase the bandwidth by going horizontally or we can go vertically or we can use combination of both of these.

In fact, I would sometimes like to say in a very simple way broad bandwidth is required for higher data rate. Now think in different way. So, we have a one patch here, another patch, another think about this for a population point of view or for people living point of view. So, if you want to accommodate more people, what we need? We need more area. So, you can have building spread in this fashion or you can have a building which is spread in this fashion or you can have this as well as this. So, by using the concept of growing horizontally or growing vertically you can accommodate more people similar concept can be used you can get better bandwidth or you can accommodate more data rate.

With that we will conclude today’s lecture, in the next lecture will talk about another very important topic and that is compact microstrip antenna because the size of the microstrip antenna is large for some application and specially in cases where we want to fit in a small area, we need compact microstrip antenna, but compact microstrip antennas have disadvantage of smaller bandwidth. So, we need to use all these broad band techniques which we have discussed and will apply those broad band techniques to compact microstrip antenna to realise compact broad band microstrip antenna.

So, with that see you next time, bye.