Antennas
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Module - 01
Lecture - 03
Antenna Introduction-III

Hello, and welcome to today's lecture. In the last few lectures we talked about basics of antennas, we talked about a simple dipole, monopole, slot and loop antennas and also we just looked at the basic introduction of microstrip antenna. So, today we will continue from microstrip antenna.

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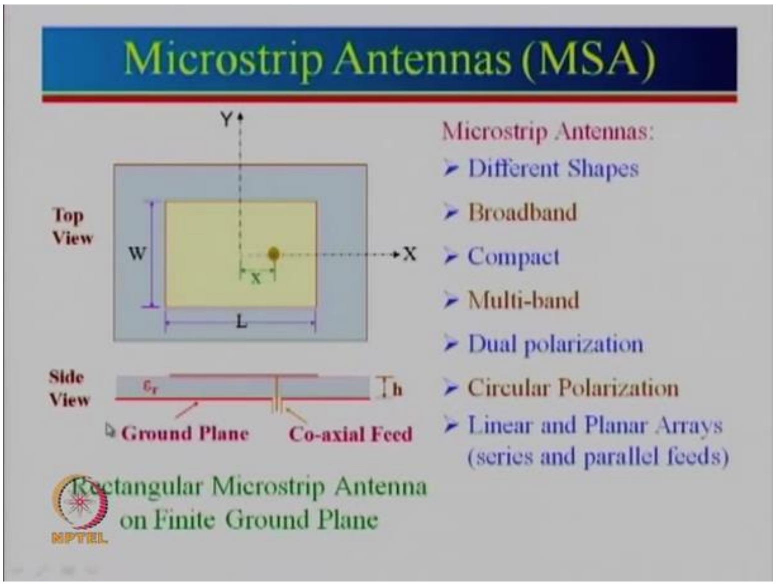

So, as we had seen a microstrip antenna is a very simple configuration, we have a ground plane on one side and we have a metallic patch on the other side and here is a feed point.

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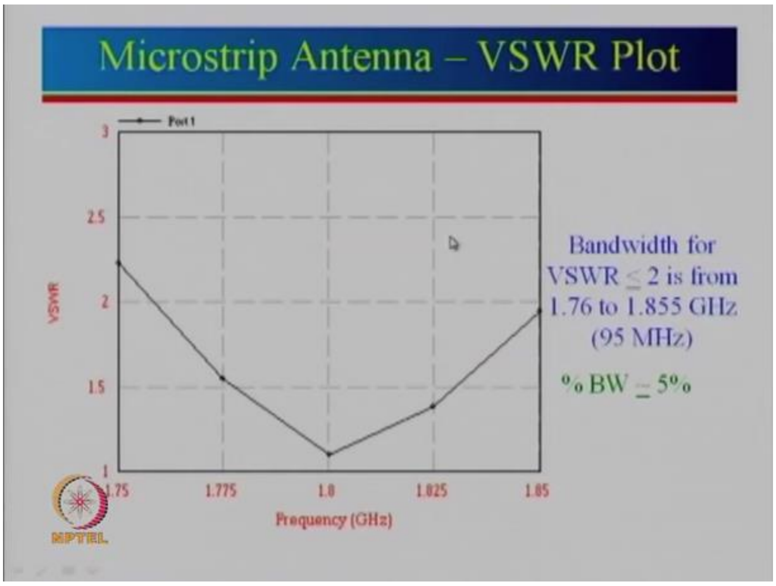

So, we have just given you one example over here where we had designed the antenna at about 1.8 gigahertz. So, this is how the VSWR varies and we define bandwidth for VSWR less than 2. So, over here if you see 1.76 is roughly this frequency and it is about 1.855 it goes there, so that total bandwidth is about 95 megahertz. And we defined percentage bandwidth as a bandwidth divided by the centre frequency which is coming out to be 5 percent.

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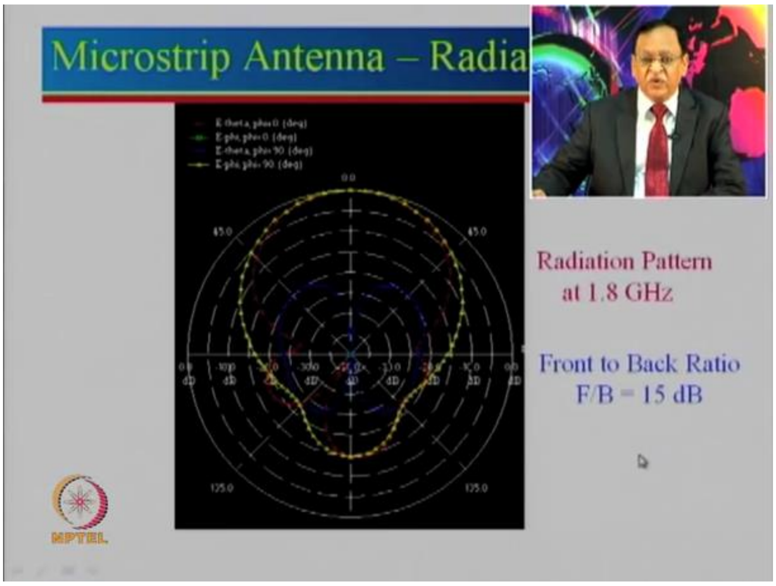

So, here in this example it shows the radiation pattern of a microstrip antenna. So, for the design antenna we have shown the radiation pattern at 1.8 gigahertz which was the centre frequency. So, you can actually see here there is a one yellow curve and then there is a one red curve here. So, it actually shows E-plane and H-plane radiation pattern and you can also see that there is a back radiation here. So, we define front to back ratio F by B. So, from maxima to this value here each scale here is a 5 dB, 5 dB, 5 dB, so that is about 15 dB. So, front to back ratio is about 15 dB.

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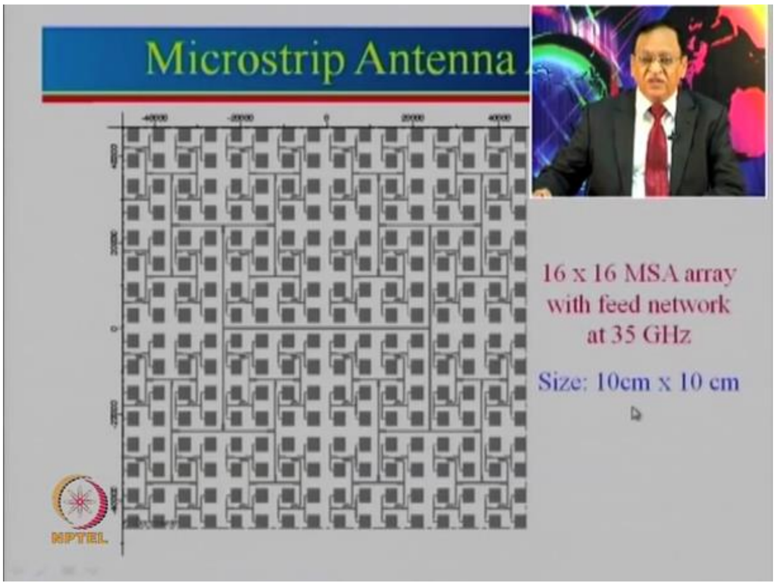

Now this is an example of a microstrip antenna array. So, one can actually see that this is a 16 by 16 so there are total 256 elements are there with a feed networks. You can see that all these elements are being fed by a microstrip line and this whole antenna was designed at 35 gigahertz and you can see that all these number of elements are fitted in a very small size of just 10 centimeter by 10 centimeter which is like 4 inch by 4 inch. So, as we move along the course we will talk in detail about how to design all these antennas and arrays.

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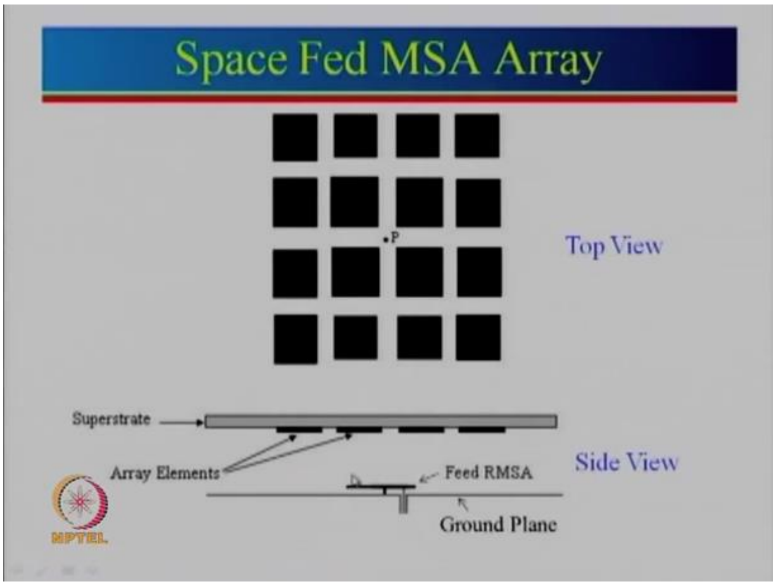

Now, that feed network creates lot of problem because of large feed losses. So, here we have actually designed an antenna where this is the fed microstrip antenna and that microstrip antenna is radiating and that a radiation from this microstrip antenna excites the patches on the top. So, this is also known as space fed microstrip antenna array. So, you can see that this is the top view of this here so that is a 4 by 4 array and we are actually feeding just a single element which is exciting this one. So, here there are no feed losses.

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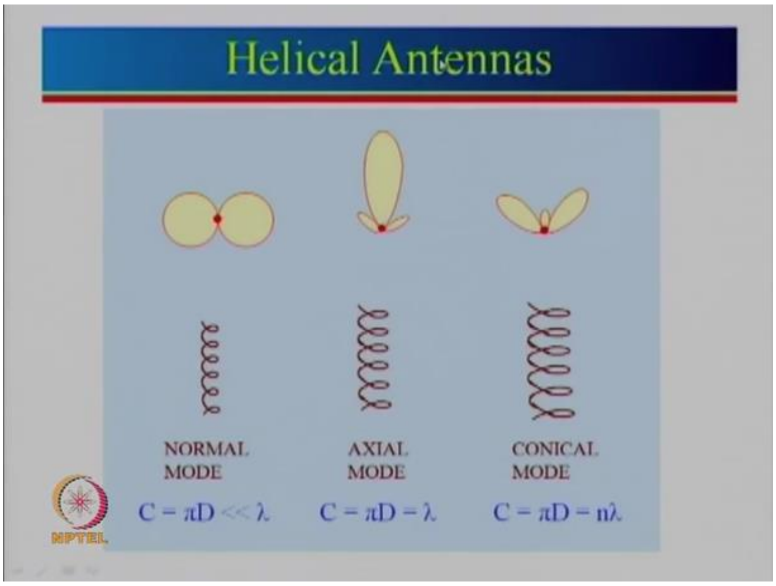

And let just look at helical antenna - helical antennas are nothing but you take a wire and just bend it around and how you bend it is important, you can bend it on a simple dielectric rod which can be hollow or a solid or you can provide some support structure also. There are three different modes in which a helical antenna can operate - a normal mode, axial mode and conical mode. In fact, the same helical antenna can work in either of the mode depending upon the frequency of operation. So, for normal mode circumference is which is equal to pi D, so this is the diameter, pi multiplied by D circumference if that is much less than lambda then that will actually radiate in the normal to this particular that access. So, this is the helical access it will radiate in the normal direction that is why it is normal mode.

In fact, this is very similar to you can say dipole antenna for a monopole antenna which is like this here. So, the radiation is maximum in this. So, instead of having a large monopole antenna now that is large monopole antenna is made compact the height is reduced so in fact, I did mentioned to you for let us say your mobile phone at 900 megahertz we would have a wavelength of 33 centimeter. So, we need maybe about roughly 9 cm height, but here the height can be as low as just 2 centimeter.

The other mode is known as the axial mode in fact, what it really implies is axial mode the maximum radiation is along this particular axis. Here you can see normal mode, the radiation is maximum in this direction which is perpendicular to the helix axis, so here the condition is that circumference is equal to pi D which is equal to a lambda. Then there is a conical mode also where circumference becomes n times lambda where n is 2, 3 or more; however, I just want to tell you this mode is very rarely used. So, in our coverage of helical antenna we will focus on these two modes.

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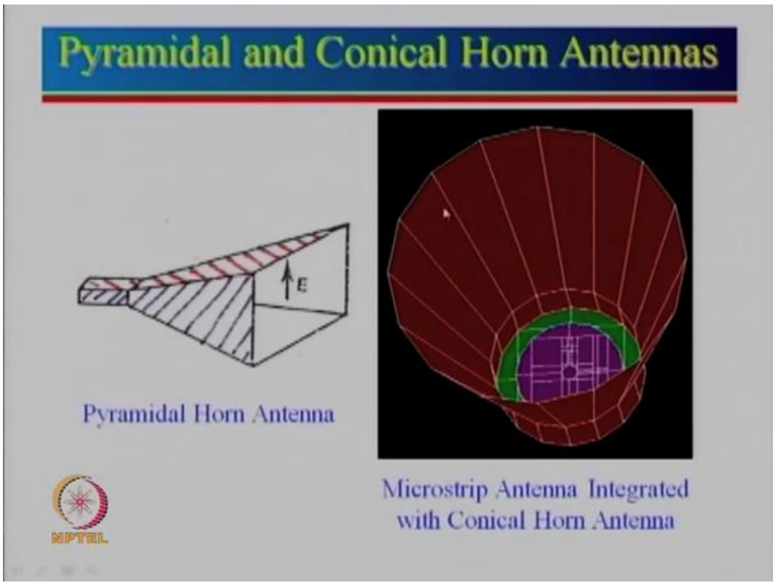

Then the next one which we will cover as a horn antenna, now there are two main types of horn antennas one is a pyramidal horn antenna in fact, there are variations are there also. So, for example, if this is a rectangular waveguide, so if you just player in one plane only then it can be E sectoral horn antenna or H sectoral horn antenna, but if it is played in both the direction; that means, you can say that this width is expanded and this length is also expanded. So, this is a pyramidal horn antenna because it just looks like a pyramid.

So, over here E field is uniform in this direction vertical and since this is a metal plate here, E will be 0 here which is that corresponds to voltage equal to 0. So, E variation along this axis is that goes from 0 goes to maximum value and then it goes to 0 here. So, the variation is half of sin or cosine depending upon how you define the angle and in an vertical direction it is E field.

Now, for this particular case here in fact, we have gone through several books and journals. Now what we realize that they do give lot of information about what will be the E field, what will be the H field, what will be the radiation pattern and so on, but however, we found that majority of the books do not give details of the coaxial feed how to feed this directly. Many a times they will show that horn antenna is fed by a waveguide and then at the waveguide they use waveguide to coaxial adaptor here, but that makes the whole length very long. So, we will also mention how to design this pyramidal horn antenna what is the role of the coaxial feed. In fact while I was investigating about this over here came out with an idea that why use a coaxial feed here, we can use coaxial feed to excite a microstrip antenna which is shown over here and we actually used a conical horn antenna.

So, if you see here this is a conical horn antenna and over here we have a microstrip antenna. So, one can feed a microstrip antenna. So, it is very simple to design a microstrip antenna even for different polarizations also or it can be used for multiband operation also or we can design antenna for whatever thing we want a horizontal polarization, vertical polarization, circular polarization, dual band, multiband and this horn antenna will utilize to amplify the gain of this particular antenna. So, we used advantages of both microstrip antenna and horn antenna and we gave the name microstrip antenna integrated with conical horn antenna. So, we will look into the details of this in time to come.

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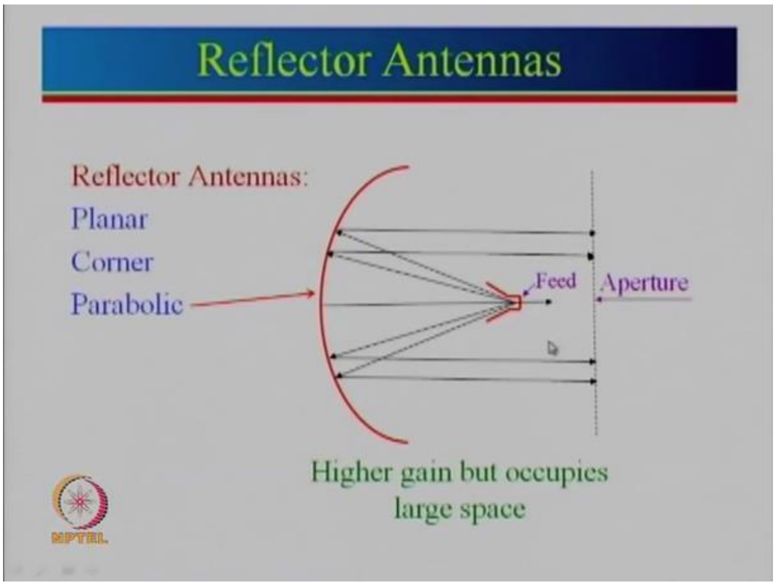

Then we will talk about reflector antenna now there are three main categories of reflector antennas are there - one is known as a planar reflector. Planar reflector is nothing but you put you have a let us say a dipole antenna and you put another let us say a metallic plate here. So, that will be a planar reflector antenna. So, what actually does is the dipole will let us say radiate uniformly in all the direction by putting this reflector so the way which is incident on this particular plane will reflect and it will go in this direction. So, basically Omni-directional will now become directional. So, it will radiate only in this side and it will not radiate in the back side. So, that is a plane reflector. Instead of this we can also use conical reflectors, in conical reflector what we do? We put let us say this antenna on a corner reflector. So, we have a one corner and the dipole antenna or any other element is put in between.

So, by changing the angle, it can be at 30 degree corner reflector or 60 degree or 90 degree or 120 degree plane will be 180 degrees. So, plane reflector will be a general case of corner reflector antenna and by changing the corner angle one can actually change the gain of the antenna which is kind of obvious. So, if it is like this here 180 degree it will now radiate in 180 degree if I make it narrower. So, what will happen because of the reflector now? It will actually radiate only in this particular cone here. So, that is how the conical antenna will give us a little higher gain.

So, typically a planar reflector may give us additional gain of about 3 dB, but a corner reflector can give a gain of additional 3 dB to even 7, 8, 9 dB gain also depending upon the corner. However, the parabolic dish antenna they are actually used to design very high gain antenna. First of all let us just look a very simple thing. So, you might have studied about a parabola equation even in your high school or initial engineering courses. So, what is the definition of a parabola? That rays which are coming parallelly from the far away, after the reflection they will concentrate at the focal point. So, it is a same principle which is used in the case of parabolic dish antenna also.

So, let us say if it is in the received mode. So, all the signals which are coming from far away point will reflect from here and they will focus on this. So, at the feed point we put a antenna. It can be done in other way around also, so feed is there. So, we feed the antenna it will radiate in this direction and then it will reflect and it will go far away point so in fact, a majority of the very high gain antennas. So, when we talk about a very high gain antennas let us say 30 dB, 40 dB, 50 dB, 60 dB and beyond, reflector antennas are the only solution right now in fact, there are antennas which are made even a half a kilometer diameter also to actually have a very narrow beam which implies also very high gain antenna.

So, reflector antennas are used. So, parabolic reflector is just one type of the antenna, but variations are also there in parabolic like this is known as a prime focus feed reflector antenna. There are Cassegrain reflector antennas are there and even the shapes are different also there are spherical reflector antenna; there are cylindrical parabolic reflector antennas and so on. So, the biggest advantage of these reflector antennas is that it has a very high gain which cannot be achieved by any other antenna as such. The only disadvantages it occupies very large space actually speaking people were using parabolic dish antenna for 25 dB or even 30 dB we have actually redesigned these reflector antenna and realized a microstrip antenna which is flat light weight occupies less volume and so on. So, when we discuss reflector antenna we will also tell you what we did and also for the feed lot of different types of feeds can be used here.

So, earlier ones had used a horn antenna as a feed or in fact, they had used a axial mode helical antenna which generate circular polarization over here. So, that is what it is used. We have even uses a microstrip antenna here also to reduce the size of this particular feed. So we will see; what are the different things here. So, basically when we want to do the derivation, so what we do? From here we take the path and this part over here. So, the beauty of this particular thing is that actually speaking all these waves after reflection they are in the same phase.

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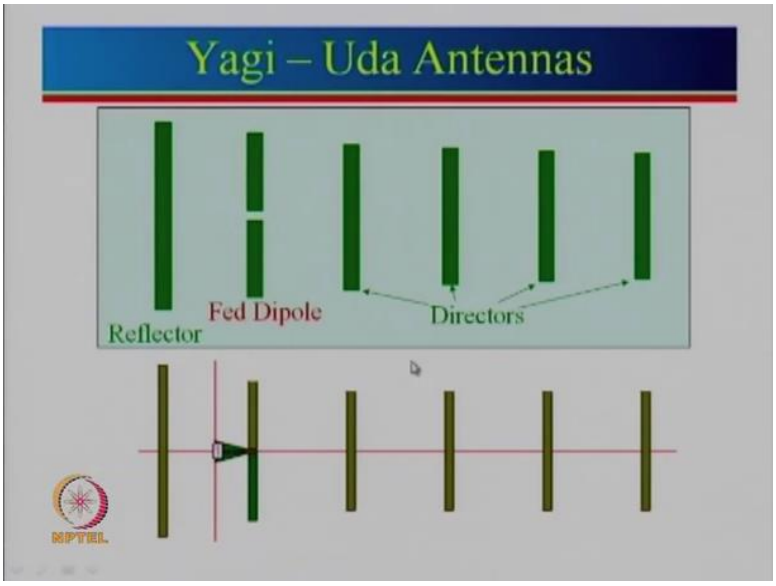

Then after that we will discuss about Yagi-Uda antenna. As I mentioned earlier these are the two Japanese inventors who invented this antenna, what is the concept here? So, what we have here? We have a fed dipole here and you can see here there is a small gap because there will be a balance feed over here. So, this will be plus and this will be minus current here and we have here a reflector antenna, now you can see that it is not using a very large reflector antenna it is slightly larger than this here. So, typically a fed dipole should be approximately equal to a lambda by 2, but when we talk about dipole antenna we will say that this length should be slightly less than lambda by 2 and a reflector antenna is taken slightly larger than that fed dipole.

So, what is the purpose of reflector antenna? Let us say this dipole antenna will radiate like this so that is the magnetic field. So, that will reflect from here since it has a larger dimension it will reflect in this direction. Now these are known as directors, so these directors will actually speaking the reflected wave goes in this direction and they direct the beam in this particular direction. So, there is a maximum radiation is along this direction. So, if you think about the array theory. So, in arrays if all the elements are fed in the equal amplitude they will radiate in the broadside direction, but this is radiating mode in this particular direction this is also known as end fire array.

The advantages of using multiple directors are that if there are more number of directors gain increases. Just think about on the lighter node think about let say in IIT, if we have more directors you really think that the gain will increase - not really, that is why we do using IIT we have a one director and we have two deputy director in any organization also. So, we have generally one director, but you can see these wires perform much better. So, more number of wires or directors will improve the gain in a more significant manner.

Now, here what we have done, we have used the printed version of this Yagi-Uda antenna. So, instead of using a fed dipole and using two different feed here we have actually used a printed dipole antenna. So, this on one side of the substrate we have this half wave length half of the dipole and on the other side of the substrate we print the other half of the dipole. So, the total length is about approximately lambda by 2. So, this will be lambda by 4, this is lambda by 4 and this is a coaxial microstrip transitions. So, from coaxial line we are transmitting and that is actually generating so, the top line is there. So, one line is connected to this one and the bottom line is connected over here and this reflector is printed and these are number of the director.

So, when we talk about Yagi-Uda antenna we will see what happens if we add more number of directors how much gain increases and what are the different parameters.

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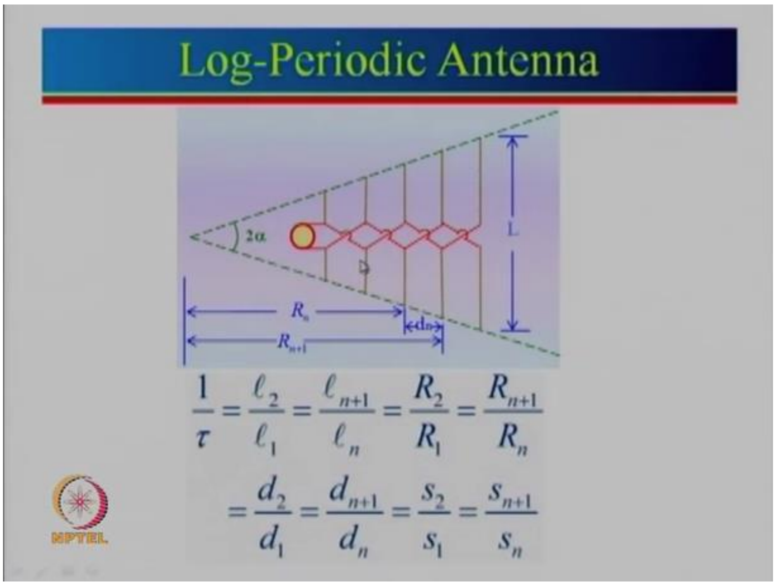

Then the next topic which we will cover is a log periodic antenna. A log periodic antenna the difference between log periodic antenna and Yagi-Uda antenna let me first tell. In case of log periodic antenna we have multiple number of dipole antennas each of these dipole antennas are fed how they are fed let us see - this is the feed point I can see that it is connected over here. Now the feeds these are connected in the opposite phase then this one here comes here and this here goes there. So, think about if this is plus this is minus so now minus goes there plus comes here then this plus goes up here this is minus goes here. So, each of these elements are experiencing 180 degree phase shape, here all the dipole antennas are fed.

Where as in case of Yagi-Uda antenna only one dipole is fed all these are not fed at all in fact, these are also known as parasitic element what does really parasitic mean? Parasitic means something which depends on other and also you can see there is a no gap over here you can simply put a length here and just to tell you. So, this is approximately or slightly less than lambda by 2 it is greater than that and these directors are all have a slightly lesser dimensions then fed dipole.

Where as in case of log periodic antenna the concept is slightly different here all the elements are being fed with the 180 degree phase difference, also the length of these dipole antennas they vary in the logarithmic manner. Even the spacing between the different elements also vary in the logarithmic manner ideally even the diameter of these dipole antennas should vary in the logarithmic manner. So, there is the ratio here so l 2 by l 1 is defined as one by top and that is known as the log periodic ratio. So, if you see here if this is the length l 2 here then this is l 1 so we take the ratio similarly all the other line so l n plus 1 divided by l n. So, if n is let us say one which is 2 and 1 if l is let us say 4. So, this l be l 5 divided by l 4.

The same thing is also valid plus 1 by tau holds good even for R 2 by R 1 which is the distance from the apex and this is the angle which all these dipoles are making. So, this is also known as angular variation of this dipole length and then even the diameters spacing all these things should vary in the logarithmic manner, but you might say that where is long here right. So, actually the log comes into picture if it takes the log of both the side so log 1 will be 0 minus log tau will be equal to log l 2 minus log l 1. So, we can actually say that all the dimensions are varying by a factor of log tau and so every next dimension will be scaled. So, from here to here to here to here the dimensions will keep on increasing by logarithmic of the function.

Same thing should happen for the diameter; however, practically all the diameters are not always change. So, suppose if there are let us say 10 elements or 20 elements of finding the wires of 20 different diameters will be difficult. So, generally they are grouped into 3 or 4 different diameters. Now the purpose of Yagi-Uda and log periodic they are actually different also. So, Yagi-Uda antenna in general are designed for higher gain; however, there is a limitation on higher gain also, typically a Yagi-Uda antenna can achieve about 7 dB for about 3 to 4 elements to about 10 to 12 dB very rarely people use for 15 dB or more. But here the limitation is the bandwidth of the Yagi-Uda antenna is relatively less of course, lot of research is going on currently where they are trying to increase the bandwidth of Yagi-Uda antenna.

However, log periodic antennas the major emphasis over here is the bandwidth. In fact, log periodic antennas are available which may have a bandwidth of 1 is to 10 for example, 1 gigahertz to 10 gigahertz or let us say 300 megahertz to 3 gigahertz. So, 1 is to 10 is very easily achievable using log periodic antenna only thing is the number of elements are large. Also log periodic antennas can give us a directional beam with the gain which may vary from 7 to about 10 dB or so, but generally people or in general practically we do not design log periodic antenna for very high gain. So, that is about 8 to 10 dB is generally the limit for log periodic antenna.

So, we will also see that how the bandwidth of these things changed. So, we will talk about that what is the effect of the diameter of the dipole antenna over all bandwidth and what is the spacing factor, how to feed these antenna, how to practically realize this log periodic in fact, there are lot of printed variations are available today for log periodic antenna. This is also printed variation; in fact I just also want to mention Yagi-Uda antenna was very popular at one time for receiving the TV signal. So, let us say in Mumbai we have a TV transmitter at Worli and that is transmitting and all the direction.

So, let us tell somebody sitting at IIT Powai. So, has through direct antenna towards Worli so they had use Yagi-Uda antenna in fact, what was the popular thing was instead of using a normal dipole they had actually used a folded dipole. The advantage of a folded dipole is that the input impedance is increased by 4 times and this was being fed by the twin cable which had a characteristic impedance of roughly 300 ohm, which provided a good impedance matching. So, log periodic antenna as I said it is being used forward various techniques for example, EMI, EMC antenna, spread spectrum technique antenna or even a broadband antennas required for ground penetrating radar applications and so on.

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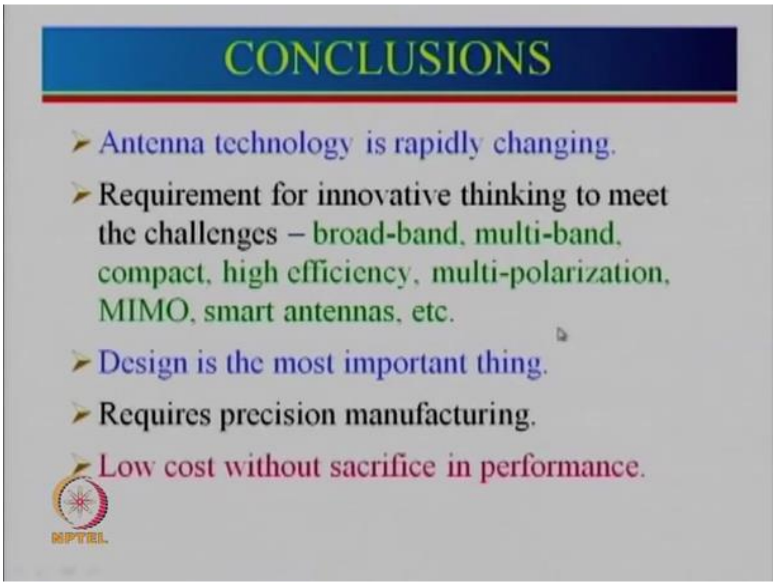

So, these are the different antennas we will cover. So, just to conclude antenna technology is rapidly changing in fact, that demand is increasing significantly. So, there is the requirement for innovative thinking to meet the challenges in fact, there is a requirement coming everyday increasing that people want broadband, why we want broadband? Because of the requirement if we have a broad bandwidth available I can send multiple channels together, I can have a data transfer which is very very fast then there are challenges about multiband antenna for example, a mobile phone required several bands.

So, we have CDMA or GSM900, 1800, 3G, 4G, GPS antenna or Wi-Fi antenna and the space required is very very small. So, we really have to put all those multiband antenna which should be compact as well as it should have a high efficiency because if antenna is not efficient then it will not radiate or receive the signal with the efficient manner. So, lot of losses will happen if efficiency is not good.

When people are demanding multi polarization in fact, there are requirements that the same antennas should work as horizontally polarized antenna, vertically polarized antenna, circularly polarized antenna. So, switches are required to switch from one polarization to another polarization. There is also requirement for MIMO antenna that stands for multiple input multiple output in fact, this is actually the new buzz words. So, lot of research is going on in this particular area this is basically to increase the channel capacity. As you know that the spectrum is becoming very expensive we are going to have a spectrum auction in September 2016 in India and government is planning to raise more than 5 lakh [FL] rupees. So, cellular operators have to sell a lot of money to buy the spectrum.

So, in order to increase the capacity enhancement multiple input multiple outputs are required. Also there is a demand for smart antennas, now again smart antennas can have multiple things which are smarter than a normal passive antenna. So, many times a simple passive all the antennas are in general passive antenna, but we can make them smart by integrating maybe oscillator within the antenna or amplifier within the antenna or built signal processing technique along with that. So, that we can have a adaptive antenna array and so on and so forth.

Now, in all of these things design is the most important thing. Now this design really depends upon what is the application for example, if you are designing the antenna for let us say satellite and defense application their cost is relatively less important, but the performance is extremely important; however, if we are using it for commercial application then that cost becomes very very important. So, one has to design the antenna such a way that it can be mass produced at a very low cost.

Now, antennas require precision manufacturing because when we are talking about a microwaves or even millimeter waves the dimensions are becoming very very small. So, any little bit tolerance in manufacturing creates problem. So, we do require precision manufacturing and that many a times leads to additional challenges also. So, generally what we do. So, suppose if the bandwidth required is let us say for GSM900 the bandwidth required is a 70 megahertz 890 to 968. So, what I generally do instead of designing for 70 megahertz design for 100 megahertz. So, that way even if there are some manufacturing errors are there it will still meet the requirement and ultimately what we really want everybody wants that antenna should be of low cost without sacrifice in performance. So, during this course of this lecture I will emphasize wherever possible how the cost can be reduced without sacrificing the performance.

Thank you very much; we will see you next time. Bye.