Antennas

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Module – 2
Lecture - 10
Dipole Antennas-III

Hello, and welcome to todays lecture on Dipole Antenna. In the last few lectures we have been talking about dipole antenna. So, we started with the infinitesimal dipole antenna, then we talked about small dipole antenna, then we talked about lambda by 2 dipole antenna and also larger length dipole antenna. And we had actually seen that let say if this is a dipole then the magnetic field is around this which is actually something very similar to a current carrying conductor which has a magnetic field around it. So, this is the magnetic field. And the electric field we had seen that on the top it is close to 0 and it has a maximum radiation in this direction. So, we have a figure of eight coming like this here and going like here.

And since we define radiation pattern as well as polarization in terms of E plane, so in this case E plane is going like this here. So, that is the E plane, so that is why a dipole antennas are also known as vertically polarized antenna, but that is only if you keep as a vertical. Suppose if the dipole is kept like this, now this is not a vertically polarized antenna now it is horizontally polarized antenna because E field will be like this maximum and going here and H plane will be around this here. So, orientation of dipole is also very very important.

Then we saw that the directivity of a lambda by 2 dipole antenna is approximately 2 dB or 2.1 dB to be more precise. And we also notice that has as you increase the length of the dipole antenna directivity increases, but the radiation pattern does not always remain in the perpendicular or normal direction to the dipole antenna. In general try to avoid using higher automotive dipole antenna, in fact if you want a high again it is better to use arrays of the dipole antenna. So, let us say we can have a one dipole like that; maybe we can have another dipole antenna like this, so that you can use an array of dipole antenna to increase the gain of the antenna.

Then from the dipole antenna we looked at the printed dipole antenna, where the instead of using a circular diameter dipole antenna we used a flat strip dipole antenna. And then we looked at the 2 different simulations; one was the strip in the air and then printed dipole antenna on an electric substrate. So, let us continue from here today.

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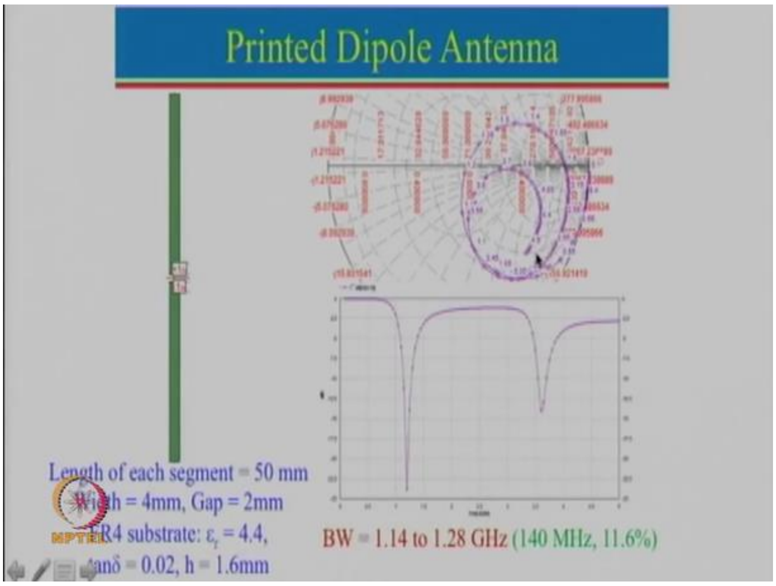

So, we had actually left at this particular point where we had a this printed dipole antenna which was printed on a very low cost FR4 substrate. And this is the smith chart plot here and I just want to go through it one more time. This is the lower frequency, at lower frequency we can see that it is capacitive, and then it becomes real, then it becomes inductive, then it becomes capacitive. Basically up to this point is length is less than lambda by 2, then this is up to about lambda and then another resonant is coming which is around when the length is about 3 lambda by 2.

So, this is the first resonance and this is the third harmonic. For second harmonic which have seen that that the input impedance is very high so that is why it is not very prominent.

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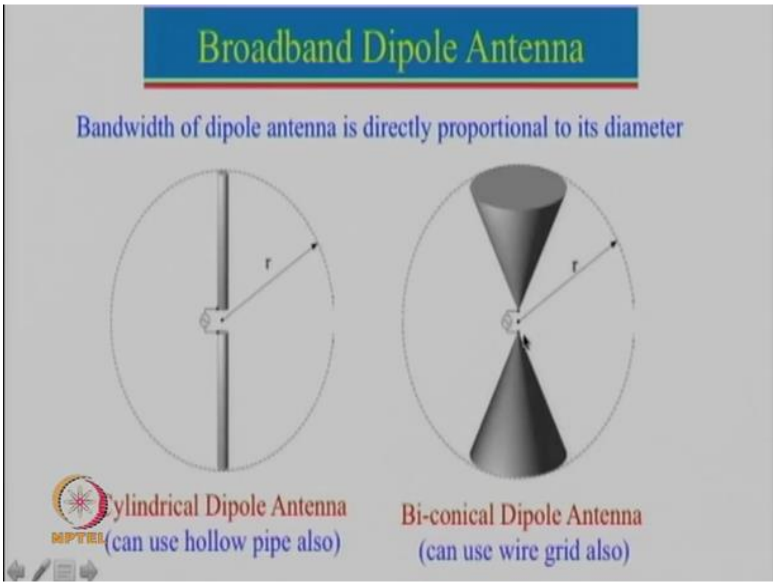

Now, we can actually increase the bandwidth of the dipole antenna by increasing the diameter. So, bandwidth of the dipole antenna is directly proportional to its diameter where this is the diameter of the dipole antenna. However, we cannot keep on increasing the diameter of the dipole antenna to a very large value and there is a limit to the absolute maximum value of the dipole antenna diameter.

The reason for that is we are assuming that the current is let us say if it is a sinusoidal current we are assuming this is 0 this is maxima and this is 0, but at that point we are assuming that the current is uniform along the diameter. But if the diameter is large; suppose just think about that if the diameter is large; that means circumference will be a large and if circumference is large then what will happen, assuming that circumference becomes almost as high as a say lambda. If it is lambda then the field variation will be than 0 plus 0 minus 0 and then the entire variation will be there. So, absolute maximum can be where diameter becomes equal to circumference which is absolutely avoidable should never be used. So, from that only we generally say that the diameter of the dipole antenna always should be less than a lambda by 10, so that the resonant does not happen across the diameter.

Please remember we can only increase the dipole diameter to absolute maximum to be lambda by 10. Now, instead of using a solid cylinder here we can also use a hollow pipe. That means, if we use a thick cylinder that will have a very large weight, instead of using a thick cylinder if we use a hollow pipe of the same diameter, but then the weight will be reduced. In fact, in general if you take a hollow pipe or you take a solid cylinder there is a hardly any change in the performance.

Now if we really want to increase the bandwidth further, so one of the other option is instead of using a cylindrical dipole antenna we can actually use a conical shape dipole and since there are 2 cones are there it is known as a Bi-conical dipole antenna. In fact, the bi-conical dipole antenna can be designed for extremely large bandwidth. The only problem is if you use cylinders like this here or conical cylinder like that the weight will become real problem. And also balancing these things and trying to put into the actual implementation becomes difficult. So, many times a wire grid is also used to design these things.

Now instead of actually spending more time on the dipole antenna I will focus more on the monopole antenna. The reason for that all these dipole antennas requires balance speed. Now in general however, from a let say microwave generator the field which is available is more like a single feed. So, we always have to design a single feed to balance or unbalance to balance network we have to design.

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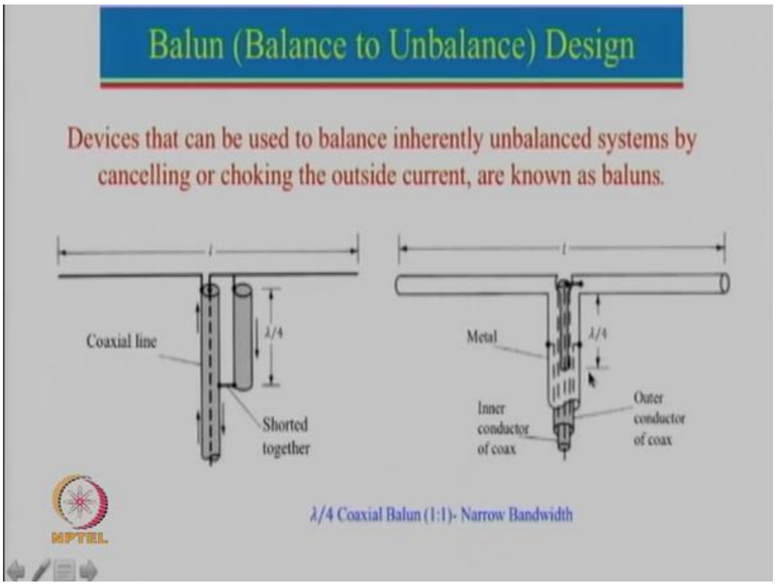

So, let just look into the different configurations which have been used. So, we use a Balun which is balance to unbalance a design. So, here we have a coaxial feed, which needs to be connected to the dipole antenna. And in between we can see that a lot of things have to be done, so this is the coaxial feed which is going. So, the outer conductor is connected over here centre conductor is connected over here, but in between the we have to add another portion which is lambda by 4, because a lambda by 4 short circuit here will act as a open circuit.

Instead of using this kind of a concept one can use at different concept also, but all of these things make things very very complicated.

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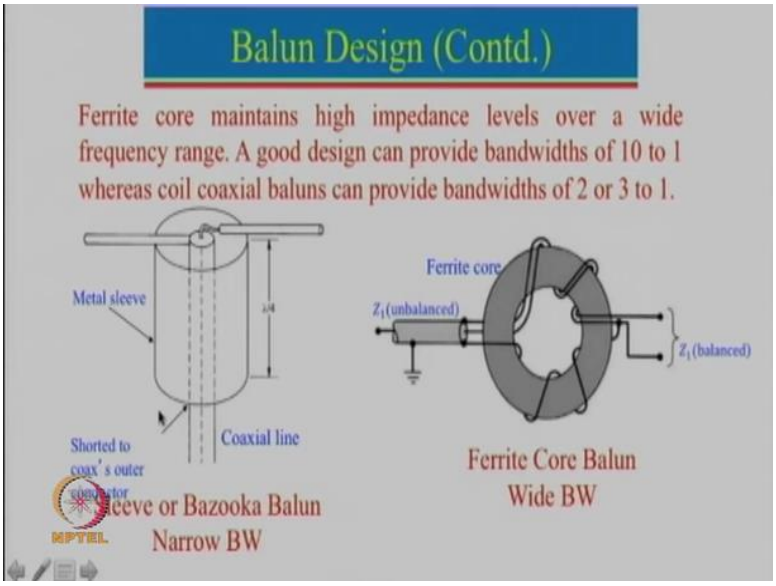

And we will just see some more configurations also. So, here is a another configuration where this is known as a Sleeve or Bazooka Balun, and in this case again also what is being done that this is the coaxial which is going over here the outer is connected over here centre is connected there, but in between a metallic sleeve has been added here of length lambda by 4 and which is shorted here, so that the short will act as an open circuit.

Then another option is to use Ferrite Core Balun; now all of these things make design and even the construction and the cost expensive. So, that is why a many a times people prefer to use a dipole antenna, instead of dipole antenna people prefer to use monopole antenna, in monopole antenna we require only single feed and the ground plane will act as a ground one.

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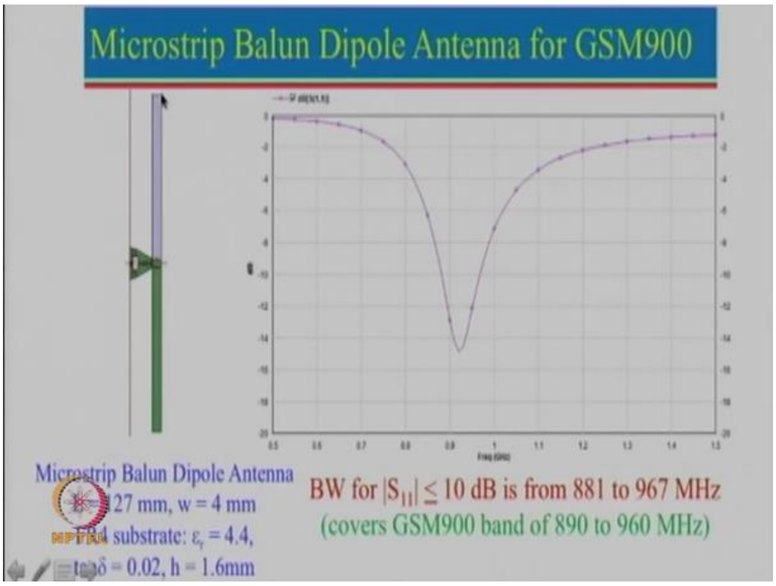

But however, we will actually talk about one very very simple way to design a Microstrip Balun. So, here what we have done this is a dipole antenna which is printed on a FR4 substrate it is a lossy substrate and a very low cost substrate.

So, what is done here that on the upper side of the substrate this is fabricated which is half of the lambda by 2 length which is approximately lambda by 4. And then the other side of the substrate this one other half of the dipole is connected. And on the bottom side you can see that there is a triangular thing here which acts as a ground play for the top feed which is coming like this here. So, basically now this is the point where we connect a coaxial connector so that greenish colour shows the back side. So, that will be ground plane connector will be connected centre pin will be connected here and this thin line which is on the top side. And on the bottom side also this paper thing becomes now the flat strip here.

Basically we have a strip of both under that substrate and above the substrate. So, one of them is connected here another one is connected there. And we have done the simulation using I e 3 d. And one can actually see that this is the reflection coefficient plot and we have design this antenna for GSM900 band which is from 890 to 960 megahertz. And one can see that over here S 11 less than minus 10 dB bandwidth is from 881 to 967. So, one can actually see that this covers 890. So, we have a margin of a 9 megahertz on one side and roughly margin of 7 megahertz on other side. So, we can say that roughly 1 percent margin is there on both the side. And that is an important thing to design because if you keep a margin then there can be substrate parameter tolerances, there may be fabrication tolerances. So, it is always a good idea to design little bit more broadband antenna then the desired frequency.

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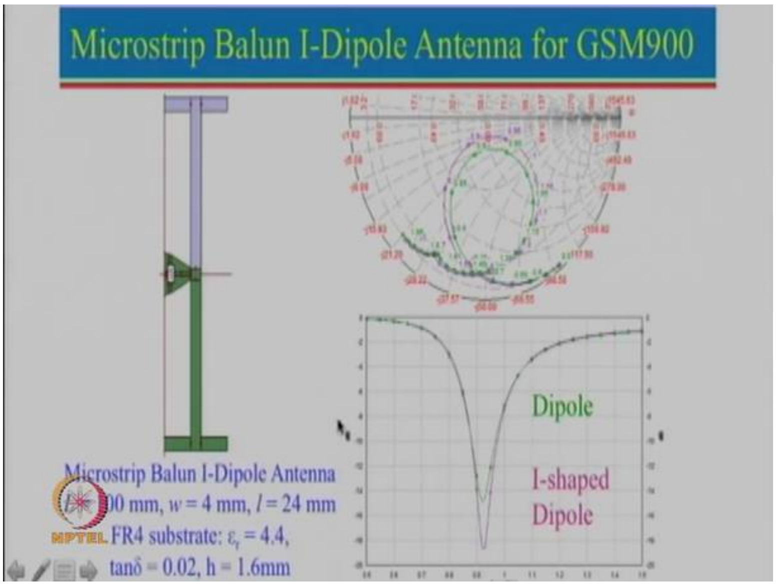

So, we will show you some more variations of this. So, over here what I have done is this is actually known as there are different names we can give: first name which I have actually written as I dipole. So, if you look at here it looks like an I configuration. This is also known as a top loaded dipole antenna. So, why do we do that? Well it has a small advantage compared to the previous configuration that now the total length is reduced. In the previous configuration we will just go back here and show you the total length was 127 mm now the total vertical length is about 100 mm. So, you can say that the total vertical length has reduced, but however we have added this length over here. In fact, the total length will be something like this here and the effective loading because of this. In fact I have just added 2 strips, many a times people also use offer especially for a normal dipole they even use a circular plate over here which is known as then again top loaded dipole antenna.

So, here you can see that total length here is 24 mm and this is about now 100 mm. You can correlate now earlier the total length was about 127 so the total length is reduced. Now this is the input impedance plot for the previous case and this one here is the input impedance plot for the loaded k. So, you can see that this one here top loaded has slightly better matching it is more closer to 50 ohm line compared to this here.

So, you can see that there is a little more depth in this one here, and because the curve has shifted up there will be little more frequency values within the VSWR to circle. So, you can see that the bandwidth is slightly increased. Now, bandwidth can be increased further also.

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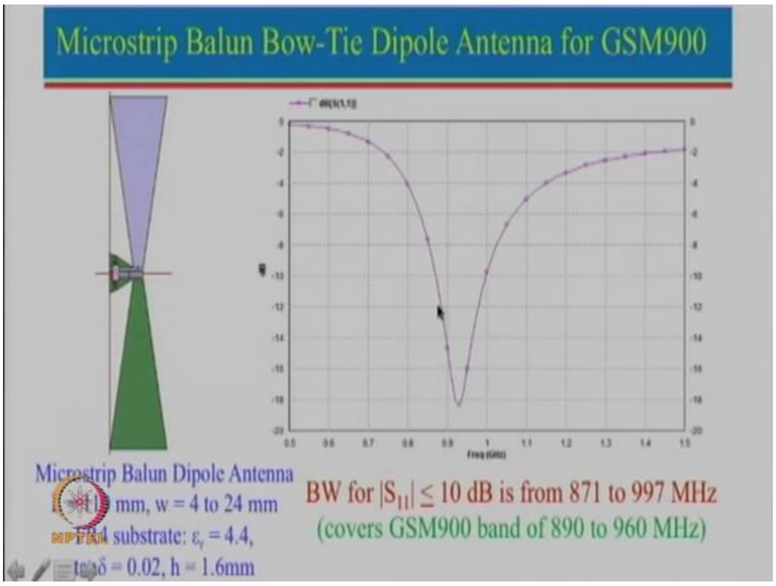

As I had mentioned that one can use a conical dipole antenna, but here instead of using a conical dipole we have just used more like a triangular dipole here. So, over here also the total vertical length is now small because instead of 127 it is about 110. The reason why now the length is reduced that it is not the vertical length only which is important, current will actually flow in the outer region here. So, it is the slant length which is now more important compared to just the vertical length over here. And by doing this over here we also got a little more bandwidth also. So, this is the reflection coefficient plot.

And one can see that for less than 10 dB the bandwidth is now from 877 to 997. So, you can see that now we have almost 19 megahertz margin on this side and we have about 17 megahertz. So, now, we have 2 percent of margin on both the sides. So, this can actually take care of fabrication tolerances in a much better way. Or one can think that 890 to 960 is the requirement. So, one can actually see that this is 900, so 890 to 960. Instead of getting a reflection coefficient less than 10 dB now we will get a reflection coefficient less than minus 12 dB; that means reflected power will be better.

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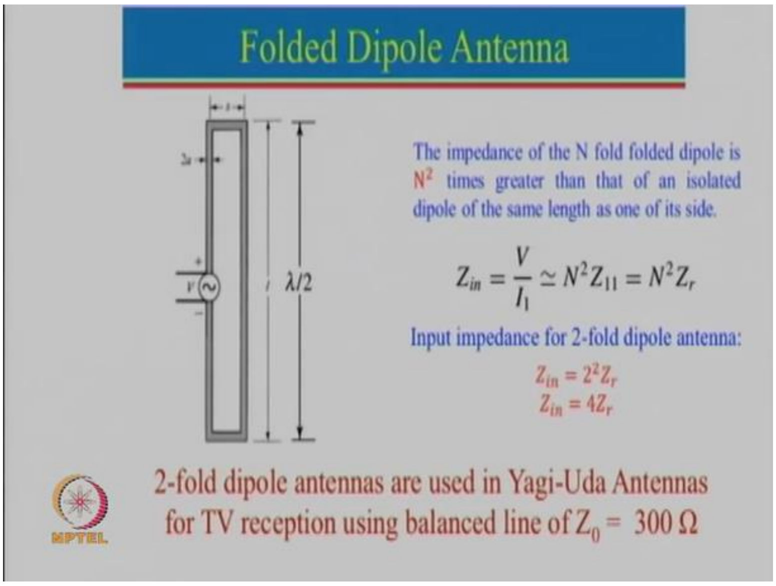

Now instead of using a normal dipole antenna one can also use a folded dipole antenna. And the reason why we use folded dipole antenna in fact, this one actually can increase the input impedance of a dipole antenna. Now we had seen that just for a simple dipole antenna like this here if you feed over here then this particular thing can actually be leading to a 73 plus j 42.5 impedance that will be if the length is lambda by 2, but I had mentioned that do not take this length physical length to be lambda by 2; I have told you that the effective length will be larger than the physical length.

So, generally speaking for this one here we should use the formula which is l plus d equal to 0.48 lambda. Then you might wonder then what should we do for the flat dipole antenna which we have done, because there is a no diameter over here there is a simple width here. So here you can use a small approximation. So, for a dipole antenna what is circumference? Circumference is equal to pi d and here you can say that width is equivalent to circumference. So, when you want to use that concept of l plus d equal to 0.48 lambda then that d which is coming over here you can actually say that d is related to circumference which is equal to pi d and circumference is approximately equal to w. So, from this you can calculate and then use the formula to find out or design the parameters of the dipole antenna.

So, over here then we should actually take this particular thing length as a 0.48 lambda which will be l plus d. So, for that impedance will be then approximately 68 ohm, but now suppose we want for some application higher input impedance, and I will tell you also the application where these were used where we need a higher input impedance. So, in that case a folded dipole antenna can be used, and by using a fold here the input impedance actually which is given by voltage by current that increases by N square.

For example, we have taken an example of 2 fold here. So, for 2 fold input impedance will become 4 times the input impedance of a dipole antenna. In fact, this has shown just the real part here, but that will be valid at the center point. So, for let us say the impedance equal to 680 ohm then you multiply that by 4. So, that will be the dipole antenna input impedance at resonance frequency, but of resonance frequency this term will become complex number.

Now earlier the application where this particular concept was being used and that was been used as a Yagi-Uda antenna. Yagi-Uda antenna basically has a folded dipole antenna then it has a reflector behind this and it actually has multiple directories in this particular direction. And this were being used earlier a several decades back you can say for TV reception, because at those times a TV receptions were mainly done a typically only a TV will be there and that TV will have a output which is 300 ohm balance line and then that will go up to the top of the roof where these Yagi-Uda antenna will be connected and it will go connect the center of the folded dipole antenna. So, that balance feed actually had a characteristic impedance of 300 ohm and you can actually see that 4 multiplied by 68 or 70 ohm is very close to 300 ohm.

So, it was actually a very popular configuration during those days. But however, there are some applications if we require a larger input impedance, I will show you one of the example also where we use this particular concepts if you add more arms here this will increase by N square. So, suppose if we use one more fold; that means 3 fold dipole antenna then impedance will increase by 3 square which will be 9 square times this here.

Now here also we can do a few additional thing also, instead of just increasing by 4 times suppose we need to increase by slightly more than 4 times then the trick is if you use this diameters slightly less than this diameter. So, we know that if the diameter is small then the impedance will be large. So, if we use a thin one here compared to this one here then this impedance will be slightly more than 4 times, whereas if this diameter is larger than this diameter here then the input impedance will be slightly less than 4 time.

So, one can control the impedance by designing these dimensions properly. However, this whole thing actually assumes that this connecting length is negligible or it is close to 0, but in reality there will always be of some physical dimension. In fact, I just want to bring your attention to something different also. If you look at this carefully does not it look like it is a loop antenna? So, it actually is a loop antenna. So, when I talk about loop antenna then I will take this particular example one more time and I will show you that this whole thing can also be analyzed like a loop antenna, and then this particular dimension plays a very important role.

So, when we discuss about a loop antenna we will actually show you that the loop dimension should be approximately equal to lambda. In fact, it is kind of similar here if this length is lambda by 2 and this is also lambda by 2 and if this is negligible then the total loop length will be equal to lambda, but if this is increasing then these dimensions have to be reduced. So, that the total loop length is approximately equal to lambda. So, when we talk about loop antenna we will bring this particular thing one more time and we will show you what can be done with this.

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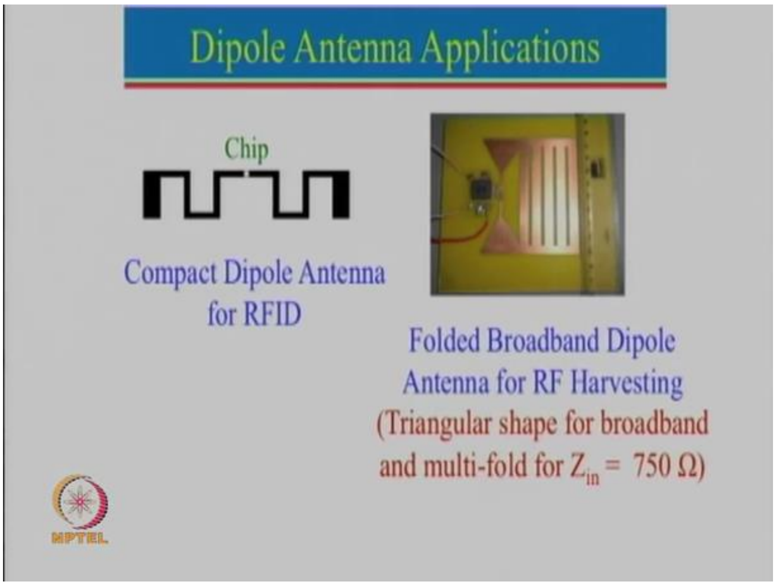

So, now I will show you some other applications of dipole antenna. The conventional applications are known, we know that a dipole antenna is to be used let us say as a transmitting antenna or receiving antenna or dipole antenna have been used in an arrays to actually design a high gain antenna. Dipole antennas have been used in Yagi-Uda antenna to design a directional high gain antenna. Dipole antennas are also used in log periodic antenna to obtain ultra broadband antenna. Modification of dipole for example, a conical dipole can be used for broadband application.

But now some other applications are also emerging of dipole antenna, so I have given a slightly different application then the conventional one here. Here is an application for RFID. Now RFID here the design is shown more for RFID band just to tell you there is a UHF band for RFID also. So, in India the band which has been given is around 866 megahertz, whereas in other countries the band is actually between 915 to 935 megahertz, but there are RFIDs also available in the frequency range of 13.56 megahertz or 125 kilohertz and so on. But here is an RFID example which is designed for let us say around 866 megahertz or 820 megahertz small dimensions will change.

And this particular thing is actually fitted I have just shown it expanded view, but it is actually is fitted on let us say of visiting card which is the small visiting card and we need to fit the antenna. So, let just say here let just take a rough frequency of say 900 megahertz. At 900 megahertz wavelength will be equal to 33 centimeter. So, half wavelength will be roughly equal to 16 centimeter. Now you cannot have a 16 centimeter length which will fit in a visiting card. So, what is actually done? You can actually bend them around. So, this length here on one side will be roughly lambda by 4 and this length is also roughly lambda by 4.

So, one can actually twist and turn them around so the total length should be roughly equal to lambda by 4, but it is actually my experience that this length should be slightly more than lambda by 4 because of all these bends. And the bends can be used in whatever fashion you need to do it. In fact, it all depends upon where and how you need to fit the RFID antenna. So, you can actually go like this here or you can actually go straight like this, then come back here then go over here, maybe you can go bend like this, you can make it as small as possible. Or you can use in a circular waveform also like this here; you can make it in the elliptical shape.

Or the idea is that it can fit in suppose you want to put this RFID on a circular shape which could be something like this. So, then we can even start put the chip in the center here and then we can go around, you can go like this here, like this here, the other one can go around. You can make whatever shape you want to do. Of course, optimizations of these shapes are important because efficiency of the antenna does depend upon how these things are bent.

You can even think about this here, let us say the current is 0 here and current is plus maximum here. So, this plus maximum goes over here, over here and then here. Now this is a plus here and this is also a plus here, but this current is going down this current is going up. So, these to field will try to cancel each other. So, is not very arbitrary that you just put arbitrary anything and it will work; no. It will probably fit in that particular area but it may not be a very efficient antenna. So, design a small compact antenna is a very interesting problem you really need to use many simulation tools, so for that you can actually use some of the packages. Let us say I have already mentioned you can use I e 3 d you can use CST microwave studio you can use HFSS and so on and so forth.

So, by using this sophisticated software you can analyze any different shape. Let me also show you one another application which is a folded broadband dipole antenna for RF harvesting. So, I will first tell you what we actually wanted; we wanted a broadband antenna for RF harvesting for all cellular bands starting from 800 megahertz till about 2.5 gigahertz. And we have actually designed this I C and this I C actually uses all these C MOS technology. For best matching it required input impedance of the order of 750 ohm. So, we have used multiple concepts here.

So, we have used the broadband concept of the dipole antenna to obtain broader bandwidth and then we have used the concept of the folded dipole antenna to increase the input impedance over here. So, we got an input impedance equivalent to about 750 ohm. And this impedance was relatively constant or in fact it gave us a VSWR less than 2 over the entire cellular band. And we use this particular configuration for harvesting energy from cell phones cell tower Wi-Fi and so on.

So thank you very much, in the next lecture we will talk about monopole antenna on infinite ground plane, finite ground plane; and what are the effects of the diameter of the ground plane, diameter of the mono pole antenna and so on.

Thank you and we will see you next time.