Analysis and Design Principles of Microwave Antennas
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Lecture – 16
Folded Dipole Antenna

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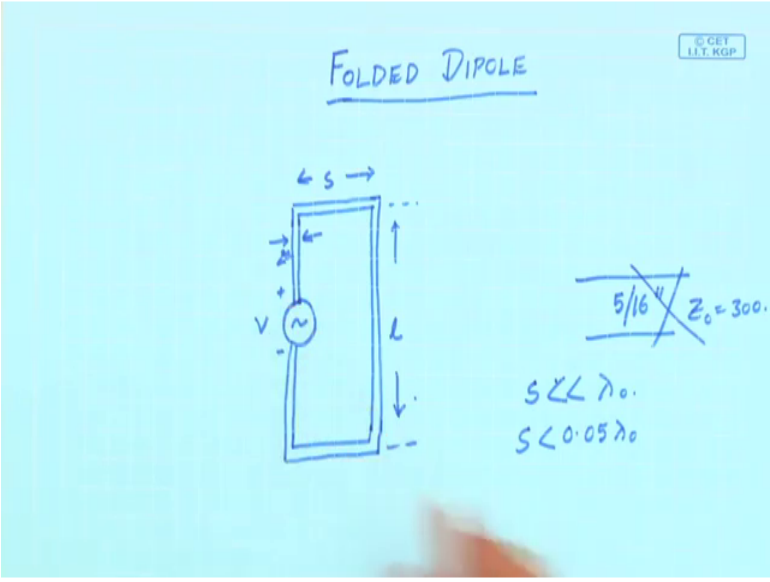

Welcome to this lecture. We will see another type of antenna, wire antenna called Folded Dipole. We have seen dipole antenna and resonant dipole has 73 Ohm resistance. So, if we use a coaxial cable of either 50 Ohm or 75 Ohm impedance, then it is a you can have a matching circuit and have a good (Refer Time: 00:49), but coaxial cable is used in laboratories but not in TV people, you TV industry does not use it because it is quite costly. Now, instead they use a two wire line, twisted line. Actually, in the nowadays you do not see because this is a cable thing because that is a more higher frequency things; so, they do not do. But, in earlier days when everyone was having an antenna, it was that user cannot afford always a coaxial cable. So, there were twisted line; that means, two lines they are twisted to reduce the interference and then that was shielded. So, basically it was a two wire transmission line.

Now, two wire transmission line; if you want to make a 50 Ohm or 75 Ohm or even 100 Ohm impedance, then the gaps are show narrow that it is difficult to fabricate with normal day thing. That is why TV people they generally use a twisted pair line which impedance is 300 Ohm which actually they you call it two inlet transmission line; actually the separation of the two wires that is typically 5 by 16 inch and embedded in a no loss plastic material for support and spacing. That is why they use for this and it has a characteristic impedance of 300 Ohm; so, this 300 Ohm, if you want to match with a dipole that was problem.

So, there was a good innovative design that instead of a dipole actually this dipole, you think that you take a very thin wire of areas and fold it in a square loop. That is called a Folded Dipole antenna. So, the length is l, the thin the loops this is a rectangular loop. So, loops what is that, loops width you can say is called S and this S is usually, S should be one thing much less than lambda naught and usually it is at less than 0.05 lambda naught. So that means, it should be quite small otherwise, there will be, the effects would not be there. It will be like a two wire antenna, etcetera. So, if you take it very small loop, then you get impedance something nearer 300 Ohm. Now, will see how the thing happens; actually here you see what we are doing that definitely this is a dipole, but here again we are making it as a transmission line of things.

So, this folded dipole can be analyzed by considering that it is some of in dipole antenna and a transmission line. So, we are interested to find it is input impedance; that means, what is the impedance it is seen when at the feed point.

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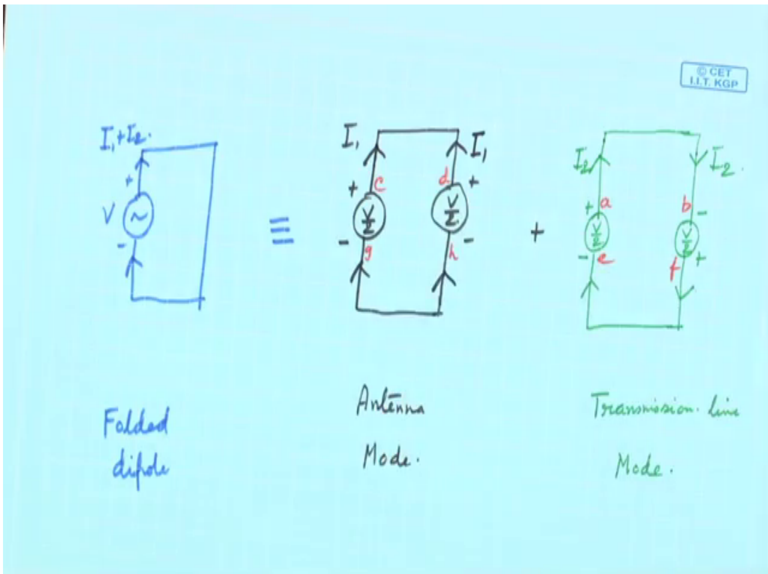

So, to do that, we make a following model that see we are having a, so this is the original folded dipole. So, let me write folded dipole. I have a current that current is coming back.

Because you see it is not like a typical dipole antenna that there was that requirement that there should not be any conduction current path between the two extremes of the dipoles ends but here, there is a path. But obviously, in these things there is a bend here and there will be a radiation. So, there is an antenna but also there is a transmission line. That is why we have written that this is sum of two current; one is antenna current, another is the transmission line current. So, this equivalently, will say that we have an antenna and I have a transmission line. So let me take that I have an antenna.

So, you see I have broken these, I have a total voltage V, here you see I have broken it V by 2 here and V by 2 here, but here you see that these two total V that is driving, this is plus, this is plus, this is minus, this is minus. So, total diving voltage at the center, if there are 2 pq potential is V and here there are, this are opposite. So, if I connect or you can say that actually in this eh end, there is no voltage source. So, these end and these end you see these two pluses V and these plus, these makes it 0. So, these are equivalent structures. Now, current flowing let me call that this is my, I 1 and this is my I 2.

So, if I have this source, this one, this one also will be I 1. Similarly, this one is also I 1, this is also I 1, this is I 2 and due to this I 2. So, you can now identify that this is the antenna mode. So, this is antenna mode because I have differential currencies in the two poles and this is my transmission mode, transmission line mode. So, we call it transmission line mode. So, these two structures are equivalent.

So, I can say that total impedance that I will see here will be sum of these. Now, why I am saying this because these two structures will give me two different impedances because this is a distributed line and here you see that I can say that c and d because of the symmetry of the structure, can I say c and d are at same potential also g and h are the same potential. So, instead of these, I can antenna mode, I am now taking antenna mode.

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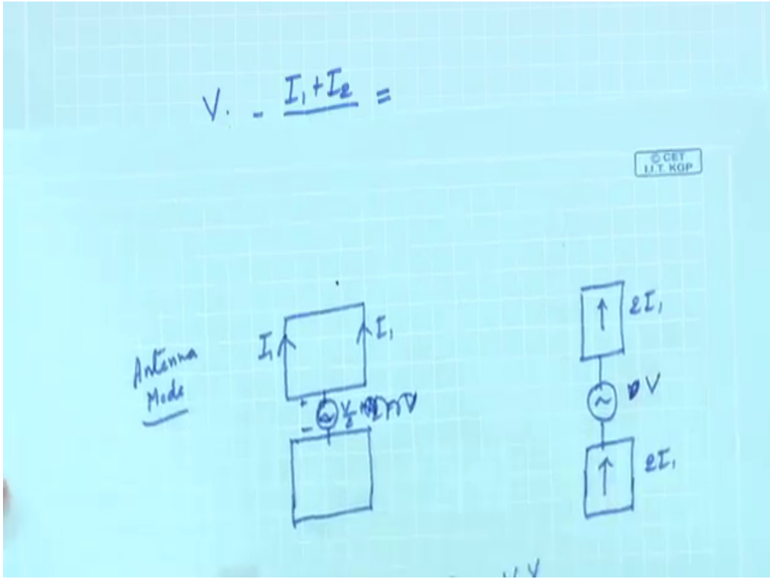

This model, so this model I can easily connect these two so; that means, the structure becomes this I do connect here similarly and V. So, this is actually V by 2 plus V by 2. So, this is V, this is connected here.

So, this is my plus, this is minus and since this is thin, this is thin, I can say this is one pole, this is another pole of the antenna dipole. And what is the current here? It was going I 1, here also it is going I 1. So, what is a total current? I can now draw it has an antenna that total current is 2 I 1 here, voltage source of V these are (Refer Time: 12:12) but these are distributed. So, it is again 2 I 1, this is going here, this is going here ok.

So, what is the 2 I 1 is equal to V into if I look at here, if the impedance is Y 1, so Y 1 is input admittance, a dipole antenna mode from two parallel conductors connected together at each end, will see ok. Y 1 is the admittance. Now, come to the so, this is my antenna mode structure, we will keep it. Then, come to my transmission line structure, transmission line model.

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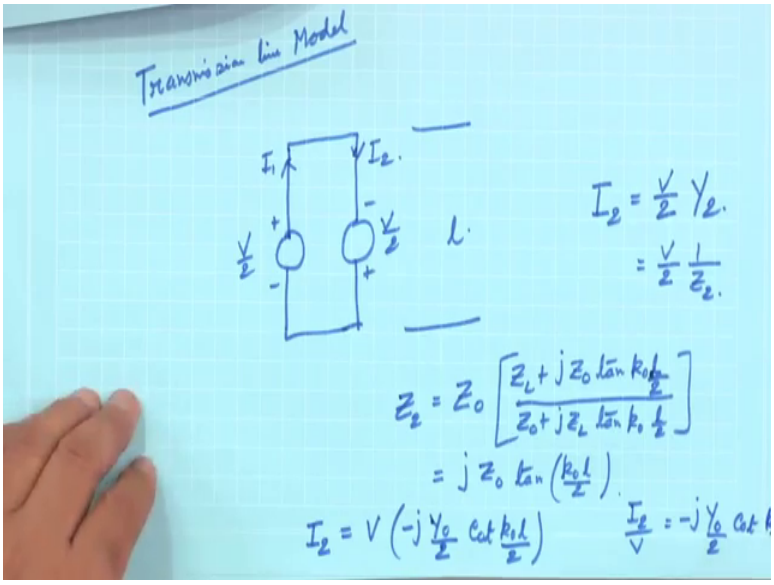

So, what I have these, these, these, these, this V by 2. So, what is this that the total length is l. So, what will be I 2 will be how much voltage each one is seeing, you see this line. So, this is V by 2 and it will be Y 2. Can I write this? Now, what is this Y 2 for a transmission line?

So, I can write is equal to V by 2 1 by Z 2 where Z 2 is the input impedance in from this point. Now, what is Z 2? Can I write if Z not is the characteristic impedance of this transmission line, then Z not, Z l plus j z not tan k naught l actually l will confuse because I have taken l, let me say that actually here the length is here l by 2 this is a shorted line am looking that. So, I can put am putting k naught l by 2 divided by Z not plus j z l tan k not l by 2, ok. So here, this is shorted here, so z l equal to 0, if we put that what will be the value; j Z not tan k not l by 2 ok. So, if I put this value here, so I will get I 2 is equal to V into minus j Y not by 2 cot k not l by 2, please check.

So, what will be I 2 by V is minus j Y not by 2 cot k not 2 by 2. So, the what is the input impedance of the folded dipole? It will be sum of this that we just seen as a super position of these two currents.

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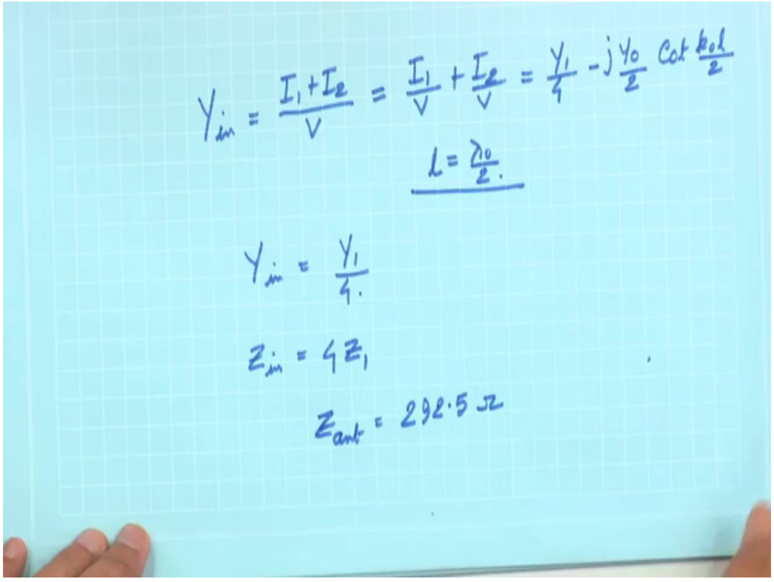

So, I can say Y in of the folded dipole is I 1 plus I 2 by V and that is equal to what is the I 1 by V of this Y 1 I 1, oh 2 I 1, this is same potential sorry, this will be V by 2 because you see for the same potential we have added here, the potentials are same.

So, this is actually V by 2. That is the mistake. So, this is V by 2. So, 2 I 1 is equal to V by 2 I 1. So, I 1 by V will be, I 1 by V will be Y 1 by 4. So, Y I 1 is equal to I 1 by V plus I 2 by V. So, from I 1 by V we will get Y 1 by 4 and I 2 by V is minus j Y not by 2 cot of k not l by 2. So, now, when l is equal to lambda not by 2 half way of dipole, this whole term vanishes check. So, Y in becomes for lambda by 2 dipole, this is Y 1 by 4. So, what is the impedance Z in? 4 in to Z 1; that means, that time it is dipole, dipole has a impedance of or resistance of 73 Ohm.

It also has, resonant dipole also have reactive part 42.5 Ohm. So, both will be multiplied by 4. So, 73 in to 4 is 292, so it can be matched to a 300 Ohm transmission line ok. So, now, if you cannot make it resonant because we have seen that actually at l is equal to lambda by 2 there is a 42.5 Ohm resistance. So, all the way it is not good to exactly make it that.

So, if we are nearby, suppose we are, so first thing is we can make a Z antenna of 292.5 Ohm which is 73 into 4 that comes there.

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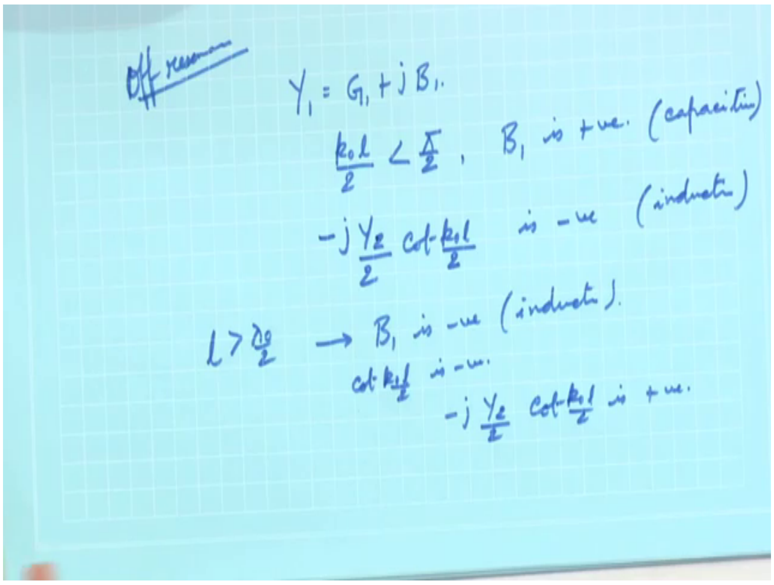

Now, if we are off resonance [vocalized-noise]; that means, generally we make that l is equal to instead of 0.5 lambda m naught, 0.48 lambda naught the so that it is fully resonance. Now, so as at off resonance this Y 1 will be G 1 plus j B 1, now for k not l by 2 less than pi by 2. This B 1 is positive this Z because b 1 is the thing.

So, it is a capacitive; that means, smaller ones we have a capacitive way thing but this is actually Y 1; that means, antennas thing it has a capacitive thing but the transmission line that is giving you minus j, you can say Y characteristic impedance Y not that am taking Y 2 2 cot k not l by 2. This is negative; that means, inductive for this condition. So, this two compensates each other that means, whatever antennas capacitive path that is cancelled by inductive thing. That is a beautiful thing similarly, you can say that on the other side; that means, if you make it higher than the so, l is greater than lambda naught by 2, then you will see that B 1 is negative; that means, it is inductive and cot k naught l by 2 is negative.

So, minus j Y 2 Y 2 by 2 cot k naught l by 2 is positive. So, a again compensates with them. So, with the this is the design engineers role that with proper choice of what will be the exact value for this, you can have the band width, you can be substantially increased over a resonance dipole; that means, if you properly do folded dipole gives you a better map that is why you can have for TV transmission that various, so apart from the impedance matching various nearby stations also could have been obtained.

Now, actually this thing, actually this by having the ratio of this conductor diameters to actually that formula that this formula what is this characteristic impedance of the transmission lines?

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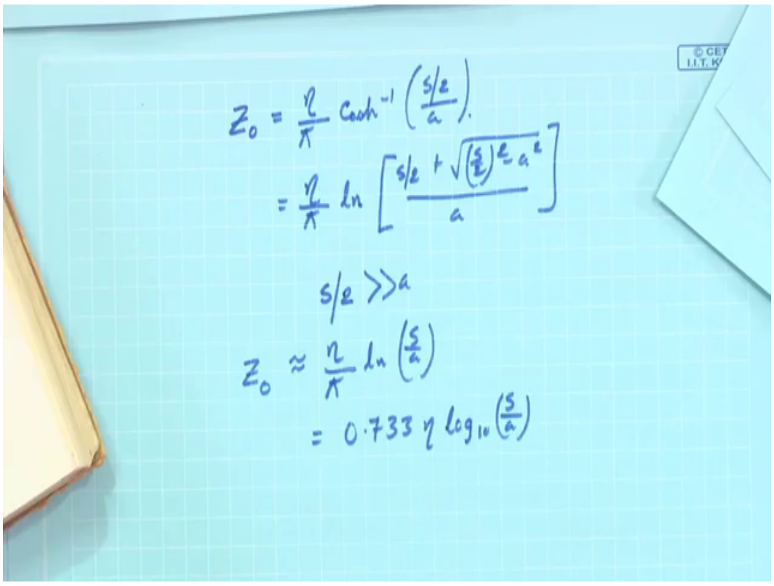

So, where we are using Z naught, so the formula that is used you see that eta by pi cos hyperbolic S by 2 by a. So, it is actually eta by pi ln S by 2 plus root over S by 2 whole square minus a square divided by a. So, what is S; if we come to the basic design things, S is the loops width and a is the radius of the wire.

So, by changing that you can get different values of characteristics impedance and generally they also has an approximation that S by 2 is much greater than a because S by 2 means when the antenna is seeing, S by 2 is it is you can say that radius. So, that radius is much should be much larger than the radius of the wires which are used to make that antenna. So, for them this Z not can be written as eta by pi under this approximation ln S by which is 0.733 eta log 10 S by a. So, you can simply find out that if you what is the required impedance, so what is the S by a ratio? So, proper things need to be.

In our days, we remember that suppose Bangladesh antenna was not available. In Calcutta, the transmission is that in Calcutta all the two, three stations, hill stations that time available, one design we look at up to that. But some mechanics they knew that Bangladesh also can be, actually Bangladesh had a very high power transmitter that time.

So, Bangladesh can be received, but audio was received, but video was not received means if you do not purchase that that was a big costly that antenna.

So, what they used to do? It is a more broader design. Actually, Bangladesh was outside, but if you do proper these selection; that means, they is to have some other S by a ratio, by that they could cater to the things so that it becomes a more broad band design and you Bangladesh things are there, for that they used to charge in those days 1000, 2000 rupees extra for that. They would not never tell what is the size, that is the property this is my (Refer Time: 26:40) ok.

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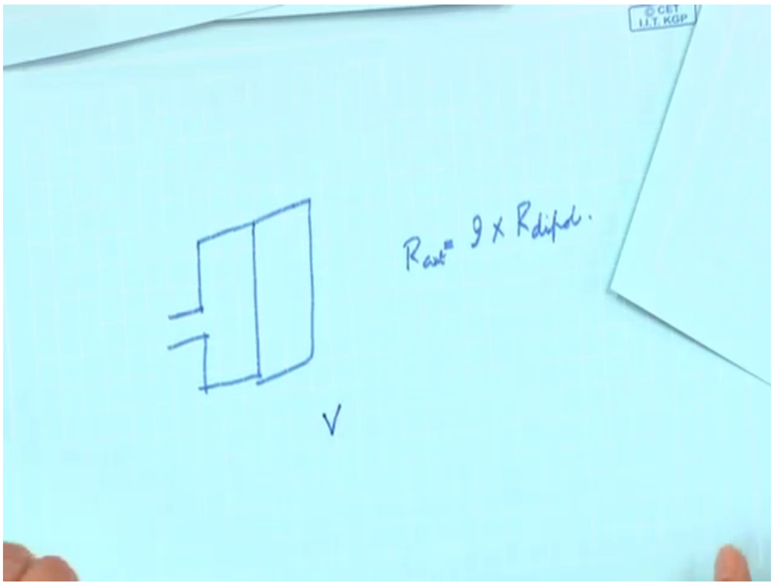

So, this thing and another thing actually you can go on doing these that. Suppose instead this, you put another one. So, here if you analyze in the similar way that R a; the antennas this combined antenna that will be 9 times R dipole etcetera.

In an array, we will see later when you see the antenna, the mutual coupling between the antenna elements they decrease the input impedance but folded dipoles higher impedance is helpful that time. So, actually will see that if you have, array antenna means what, this is not an array antenna please remember because here am driving only one, but if I drive two, then the if you combine a self impedance, two self impedance together, but the mutual impedance will be left. So, to put that impedance up, you need some non impudent things like these? Actually, this is also say non driven thing.

So, when will discuss the (Refer Time: 28:17) array, the concept is this. The directors etcetera actually they are for impedance matching also that they are passive ones. So, passive ones increase the impedance of the antenna, but you will have to have the proper dimension etcetera. So, you can also say that equivalent circuit of this folded dipole is something like this.

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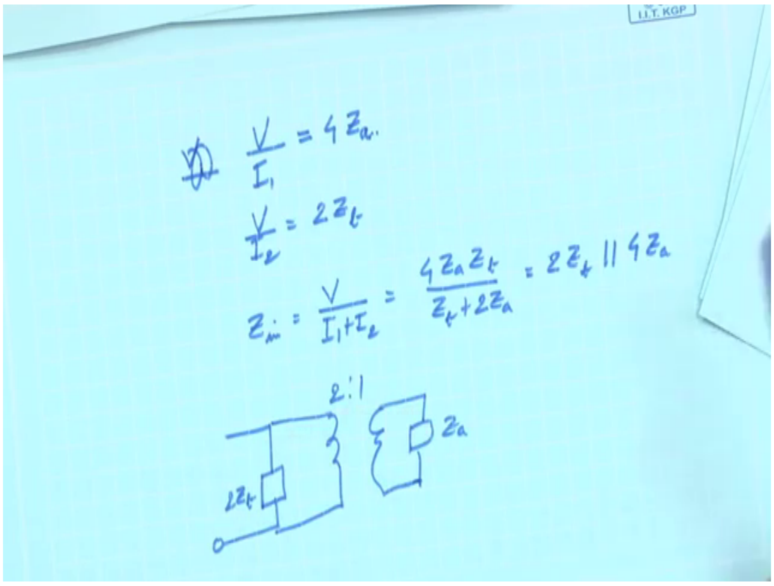

Let me again write, let me take that what about the impedance that time we calculated, can we say that V by sorry V by I 1 referring to that antenna mode those diagrams, we have 4 Z a. This is antenna mode and V by I 2 was 2 Z t this is transmission mode.

So, Z in stand out to be we have found out, I 1 plus I 2 and that is 4 Z a Z t by Z t plus 2 Z a a, if you do this just it will come out. Now, this can be seen as 2 Z t parallel to 4 Z a. So, what will be the equivalent circuit of the folded dipole? Can I say that I have first a 2 Z t. So, this is 2 Z t, then actually I have a transformer and this side I have the Z a. Now, this ratio is 2 is to 1. You see, this Z a; that will come here this side parallel, it will be this is 2 is to 1 means this will be 2 Z a 2 Z t parallel to this. So, this is the a that antenna mode impedance that is stepped up by four fold. This transformer impedance appears in shunt with twice the transmission line mode impedance by proper charge, we can remove transmission line mode impedance that we have already seen.

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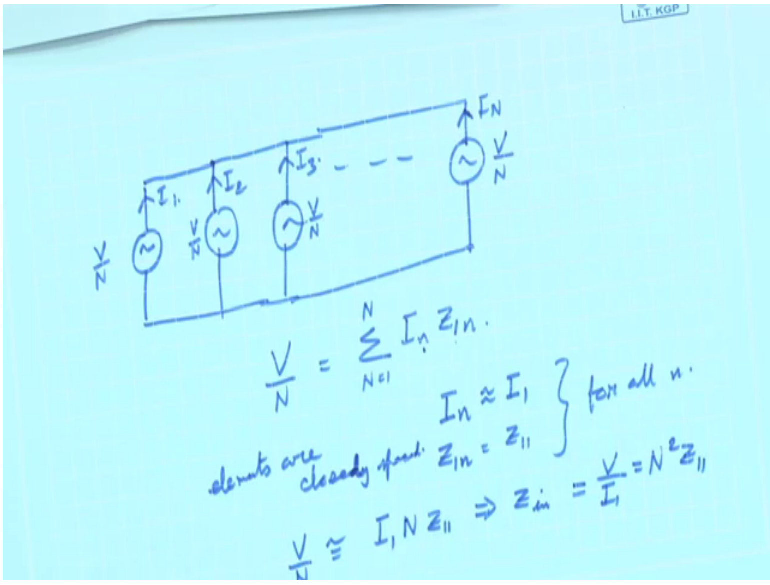

Now, lastly please note the for n element case, it becomes that, so voltage across has conducted we can write V by n will be n is equal to 1 to n in Z in; that means, actually this is the, if we have so many drivers, then this will be I 1 Z 1 1 plus I 2 Z 1 2 plus I 3 Z 1 3 etcetera, etcetera. Now, since elements if they are very closely spaced, then we can say that all in s will be equal to same and Z 1 in will be equal to Z 1 1. This is true for all n provided elements are closely, closely spaced.

So, what will be V n? V n will be approximately I 1 n Z 1 1. This implies, what is your Z in is V by I 1 is equal to n square Z 1 1. Actually, this is the idea that it becomes a n square factor ok; like here, it is only 2. So, it will is 4 times Z a. If you have 3, you have 3 times etcetera because actually in the antenna mode, this is happening ok. So with this, this is a very good antenna for dipole in one day when TV transmission was directly to home antenna reception. This all this folded dipole was very popular; nowadays, since the whole things is done at cable operators and individual things are not there or you use these antenna; instead of wire antenna, folded dipole is not seen nowadays, but concept wise, this is one of the very popular successful design of wire antenna, ok. So, some of the wire antennas we have seen. Next, we will see some other very practical antennas; obviously, some of them will be array antennas which are also very useful and then, we will see some other things in other classes.

Thank you.