Networks, Signals and Systems
Prof. T. K. Basu
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 03
Distributed and Lumped Parameters 2 - Port Networks

Good morning friends, yesterday we discussed about different connections of voltage and current sources and then we discussed something about knowledge writage, different types of knowledge writage then dot convention and we will continue with that. The dot conventions that we adopted yesterday I will just repeat if you have a core like this, if you are having a coil, say coil A or coil 1, 1 dashed and another coil having the terminals 2, 2 dashed, you see the coils are round in the same sense, the coils are round in the same sense then if the current if I call 1 as the starting terminal, 1 dashed as the finishing terminal.

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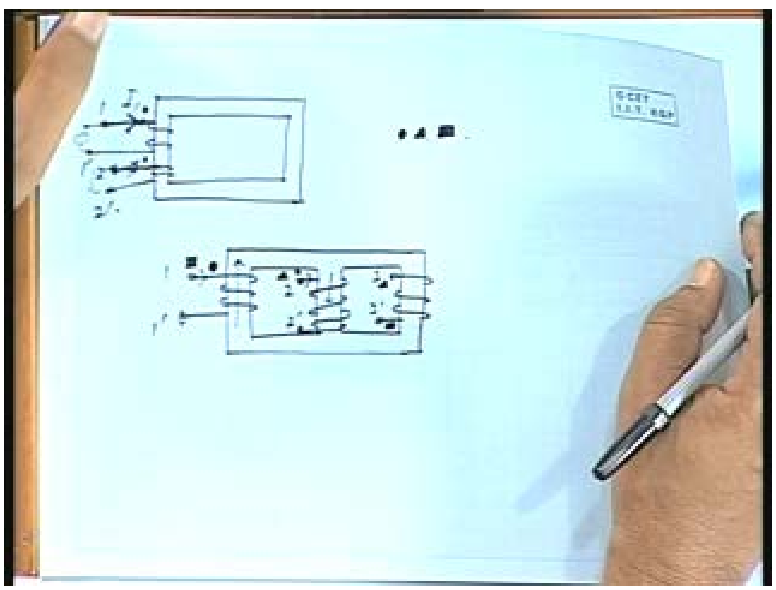

Similarly, 2 as the starting terminal 2 dashed as the finishing terminal if current through terminal 1 enters into the coil okay like this and current through 2 also enters through this coil then both of them give raise to a flux in the same direction all right or in other words, if we connect this with the source and if you short circuit this one externally, the current here will be flowing out of this terminal and entering through to 2 dashed all right because it will be having by transom reaction okay if you are having an alternating voltage say applied here then the current will be going in this direction okay that means what, it means that if the coils if the coils produce identical fluxes when they are excited separately then those terminals the starting terminals will be shown by dots that means an a current entering here corresponds to current entering here from an external source they are identical that means they give rise to the flux in the same direction, this is easy to remember all right.

Now I will give you example, you try to find out whether this if this particular coil just 1 minute, this particular coil arrangement and the dot conventions are correct; you are having a teroid with a central link okay. Now you are having a coil like this then you are having 2, 2 dashed then this one 3, 3 dashed I put a circle here then there are many coils when there are 2 coils then you can have 2 dots, when there are many coils then you have dots, triangles, rectangles etcetera for showing the polarity all right, all right that is the interconnection the mutual dependence of the 2 coils mutual inductance when it comes into play, so 2 coils when we have 2 show their interconnections all right.

You can use this type of set of conventions. Now suppose we have a circle here, a dot here and we want to use the dots between coil 1 and coil 2 where should I put for 2, 2 dash terminals where should I put the dot should it be here or here. Now you see this is the direction of the coil so if I send a current here, a positive current here then what will be the direction of the flux, does it go upward, it does okay what about this one, forget about the third coil for the time being what about this coil run through 2 mind you the winding sense is opposite, so it will show downward, so so if so for is the core is concerned it is going like this it is in the same sense okay, so this will be also dot, all right.

Now between 1 and 3 suppose I put a rectangular block between 1 and 3 then 3 or 3 dashed should be the rectangular block, 3 dashed you see the winding sense here the windings are both in the same sense but then this will be trying to send in a flux in this direction, this will try to oppose that, is it not. So 3 dashed should be the corresponding terminal, is it all right between 2 and 3 therefore suppose I have triangle we use this symbol between 2 and 3 then where should be the corresponding triangle, here now between this and this, see when I send a current here, it sends the flux all right, when I send a current here it sends the flux like this, so it is in the same direction again.

So it should be a triangle here, is it all right? So this is how you should put dots and other symbols when there are multiple coils you first see the sense of the current and try to find out what should be the direction of the flux through the core and what would be the flux established by the other coil if they are in the same sense then the both the entering currents are positive, in a sense that they are matching so you put the dots accordingly from the entering terminals. Next, we go to distributed and lumped parameter and lumped parameter systems, for all practical purposes in our laboratories we assume a resistance for example, in a rheostat, in a rheostat you wind the resistance over a tube okay.

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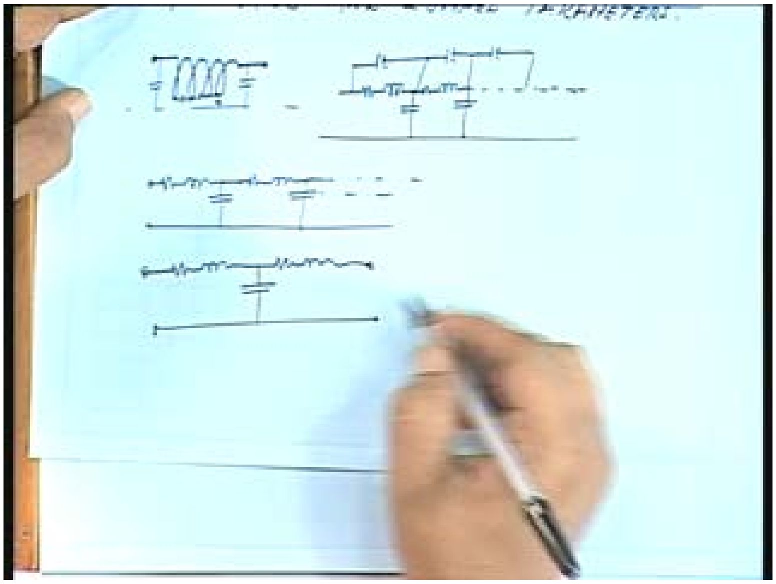

We assume the inductance is negligible all right, we take only the resistance value but there is an inductance there and not only inductance between the turns there will be inter-turn capacitance okay. So between the turns we can assume between them there will be capacitance also there can be capacitance to ground all right, capacitance to ground. So these values will be perceptible at very very high frequencies normally in our power frequencies we do not find their effect, so we consider resistance to be an ideal one.

So as the frequency goes up, you will find one turn if I take one turn as basic unit, one turn will have some resistance, it will also have an inductance and then there will be a capacitance to ground then there will be a resistance, there will be an inductance, second turn and again capacitance to ground and so on okay, not only that there will be inter turn capacitance. So I can also across each terminal I can put approximately a capacitance.

So it will be distributed like this even in a transmission line, in a transmission line, power transmission line you have resistance, inductance say, we calculate on the basis of a kilometer or a mile, 1 kilometer length has so much of inductance, so much of capacitance and then after 1 kilometer if the capacitive value is perceptible if it is a very high voltage line extra high voltage line then the capacitance to ground will also be quite appreciable and we denote the a we represent the transmission line like this.

So this is the example of a distributed parameter system at low frequencies or even in power frequencies a for a low length and low voltage system, say 220 KV or 100 and 10 KV or 33 KV lines and 50 to 100 kilometers, we normally take a simple approximate representation, say one capacitance to ground and the total resistance and inductance will be distributed on both sides, either in this form or in this form, we represent the transmission line, it is in a lumped form.

So it also depends on the nature of the problem at very high frequencies we cannot neglect these effects these capacitance and the series inductance, see inductance value even if it is very small if the frequency is multiplied many fold say 10 kilo Hertz or may be to the order of mega Hertz then this impedance is quite substantial and this will also tend to be almost a short circuit that means the capacitive current will be quite substantial, so you have to take care of the distributed parameter values.

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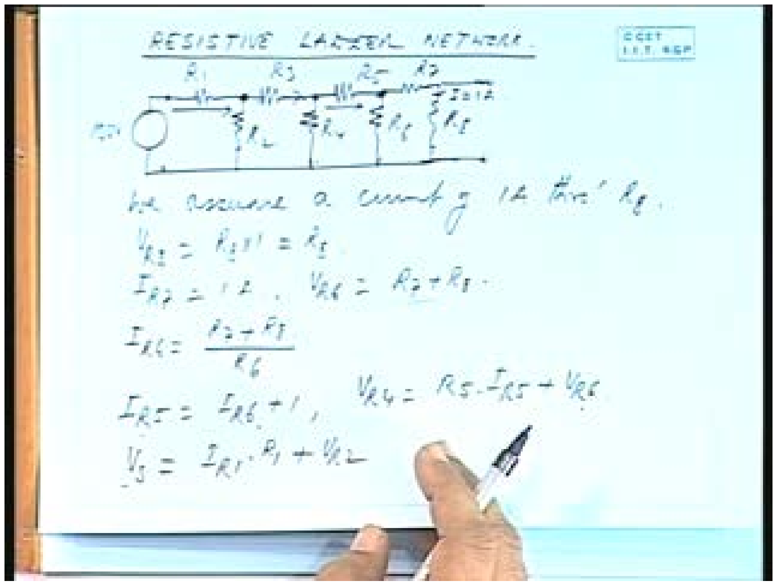

Next we take up ……. suppose we have a voltage source then you have resistances like this and so on. So this is R 1, R 2, R 3, R 4, R 5, R 6, R 7, R 8, suppose you are interested in computing the currents or voltages for a voltage of 100 volts applied here, what will be the current through this, what will be the voltage across this and so on okay. Now we can assume either the voltage or the current through this last element R 8 as unity.

So let us take 1 ampere current flows through this, we assume a current of 1 ampere through R 8 then what will be the voltage across this resistance VR 8, it is R 8 into 1 ampere, so many units voltage then the current through R 7 is also 1 ampere, the same current so what will be the voltage across VR 6 okay IR 7 is also 1 ampere. So what is VR 6, so R 7 plus R 8 into 1 then what will be the current through R 6, IR 6, R 7 plus R 8 divided by R 6 all right, what will be the current through R 5, IR 6 plus 1 ampere, this 1 ampere plus this. So what will be the voltage across R 4, R 5 into this current which is this one R 5 into IR 5 plus VR 6, VR 6, VR 6, I have already computed here.

So IR 5 have computed here, so you substitute here you get correspondingly VR 4, once you know VR 4 you can calculate IR 4. So alternately you compute the voltage across these resistances that is at these nodes and next you compute the current that is drained out through the shunt elements, once you calculate this current add with the previous current you get this current IR 3, IR 3 multiplied by R 3 is the drop here, add with the previous voltage at this node, you get the new node voltage at this point and so on.

So you alternately calculate current and then voltage at that node current and voltage and so on. So you come up to this point all right. So going like this how much will be the voltage here at the source, it will be IR 1 into R 1, voltage at the source is IR 1 into R 1 plus voltage at this node VR 2 okay which you can compute from this node voltage adding this value I can compute this, so as we go backward we can calculate Vs suppose that Vs comes out to be 20 volts okay. So for 20 volts of supply we could get 1 ampere current, so for 100 volts of supply what will be the current see you jack up the current by 5 times okay, so for 20 volts it is 1 ampere for 100 volts it is just a simple computation, scale it up by that factor. So you can compute now all the voltages and currents all these voltages everything will have to be multiplied by 5 okay.

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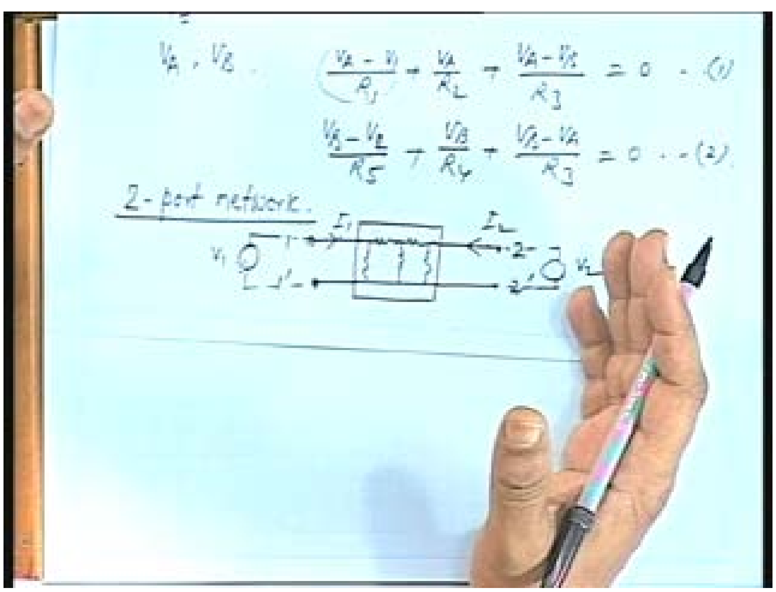

So all the node voltages everything is scaled up by 5, this is the very simple technique when you have to calculate the current when there is a single source and a structure is like this a data network okay. We could have started with the unity value of the voltage, voltage across this is 1, 1 volt here how much is the current V by R 8 then how much is this current same V by R 8 then plus R 7, V is 1 volt, so 1 by R 8 plus R 7 and so on. You can calculate before we go to 2 port network, I will just very briefly mention about some of the network essence of some of the basic network theorems that is what we have learnt in the first year class, most important is nodal analysis, it is this analysis which we apply quite often in most of the circuits and it will be easier say, let us have a simple network, I have taken 2 simple sources.

So V 1 and V 2, say R 1, R 2, R 3, R 4, R 5 they can be replaced by j aliased impedances when we take up later on in the Laplace domain, the impedance functions will be using those impedance functions. So here we take one reference node take it as a ground, this only reference with respect to this reference, we define there are 2 junctions here, we can see A and B okay, when we say junctions there could be at least 3 elements which can form the junction all right that will be easier there is no point taking a node here because the current that is flowing here is a current flowing here.

So additional nodes will be unnecessarily increasing the number of variables. So we will try to minimize the number of variables. Suppose we assume the voltage of this node with respect to the ground as VA and similarly, the voltage at this node as VB at this point we apply Kirchhoff's current law, Kirchhoff's current law okay. You take a point and assume all the currents are going away from that node, what will be the current through the first element as if VA is at a higher potential, it may be negative or positive we assume that VA to be at a higher potential then VA minus V 1 divided by R 1 will be the current through this. So VA minus V 1 by R 1 plus this current plus this current plus this current will all similar how much is this current VA by R 2 plus then this 1 VA minus VB divide by R 3 is equal to 0 is the equation 1, we will have the same then VB minus V 2 by R 5 plus VB by R 4 then next VB minus VA by R 3 equal to 0, okay.

Now you see in the first case we have taken the direction of the current like this, in the second case we assume the current to flow like this because we do not know the direction but at that node we are applying Kirchhoff's current law okay. You solve for these 2 variables V 1 and V 2 from here, you get the values of these 2 voltages which may be somewhere in between V 1 and V 2, we do not know the exact values they will be depending on the resistances that you have put and also the source voltages. In case of, in case of ac circuits this will be a complex phasor, a voltage with a phase angle, this also be a voltage with a phase angle and this will be a general impedance in the form say A plus JB or A minus JB depending on whether there is an inductance or a capacitive element along with the resistive element okay. So these equations will be complex, you have to solve in that case both for real and imaginary parts okay.

So you can get V 1 and V 2, VA and VB once you know VA and VB for a given set of V 1 and V 2 you can calculate these currents just substitute in the first part of this equation you get this current, second part will give this current, the third part will give this current so all the branch currents can be calculated from there once you know VA and VB. So this is how we solve problems where you have more than one sources.

Now we come to very interesting network that is 2 port network. So far that in your first year class we did not mentioned about ports, we assumed number of sources here and there all right, here we applied Sobuchen theorem, nodal analysis or mesh method and a loop method and you have calculated the currents voltages etcetera. When we have 2 distinct ports from where we can vary the voltages or the currents the internal connections are not shown here there that can be any complicated network there can be any type of inter connections in between but there are 2 terminals 1, 1 dashed to pear sub-terminals and 2, 2 dashed brought out and you have sources connected at these points say V 1, V 2 sometimes we are interested in studying the properties the behavior of the network that is shown inside the block and we excite externally from 1, 1 dashed or 2, 2 dashed or both like in a power system side.

You have feeding power at this place place at Kharagpur, suppose we have a genetic station, we have a feeding power to your network there can be another genetic station at Jamshedpur. So we can assume the 2 sources to be connected like this in between you have the network given by the transmission line they can be sub stations joint power, so it represents a 2 port network okay.

Now we are interested in finding out the relations between one set of parameters in terms of the other that is there are 4 parameters, 4 variables, sorry, 4 variables we assume the currents going inside the network as positive. So there is a voltage say at Kharagpur, voltage and current there will be a voltage and current at the other end at Jamshedpur. So there are 4 variables V 1, V 2, I 1 and I 2, 2 of them are known then, the other 2 are also fixed any 2 of them can be given to you, the other 2 will be related by the property of the inter connection.

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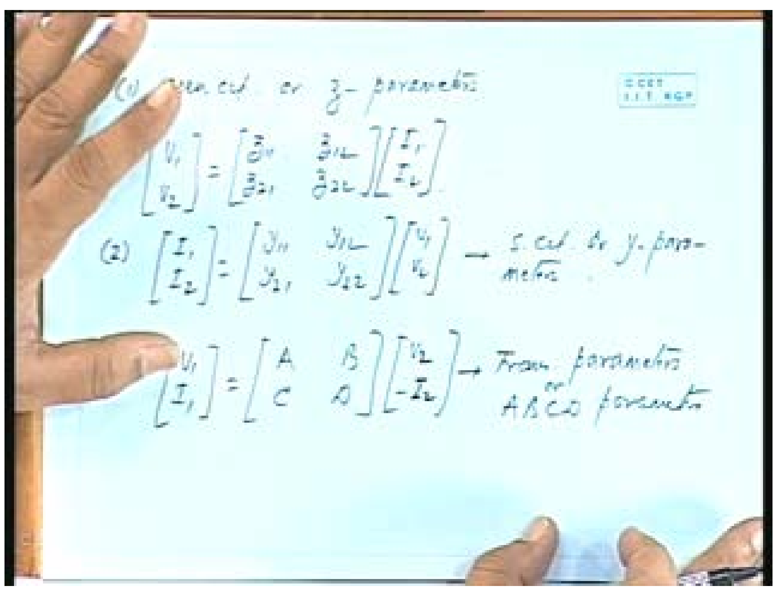

So how do we express the network parameters, the inter connected elements that decides the property of the network how do we represent the 2 sets of current voltages by different methods okay. So one of the the we call them parameters these network values that we shall be computing are known as parameters. The first one is open circuit or Z parameters, let us see what it means suppose you are given the voltages at the 2 ends, we are feeding the network from 2 ends with voltages V 1 and V 2, you are asked to compute the currents what will be the currents I 1 and I 2 given the network this is one problem that you have normally used in Sobuchen theorem, you take V 1 at a time V 1 short circuit the other end then V 2 short circuit this end, calculate all the currents okay for the network and then when you excite both of them that will be the algebraic sum.

We represent by an by a matrix equation we can represent V 1, V 2, I 1, I 2, I am sorry if you are given the currents I 1 and I 2, I am injecting so much ampere from terminal 1, 1 dash I am injecting so much current from the other end then what will be the corresponding voltages, this can be one problem. So we express if you just substitute I 1 and I 2, if these parameters are known this matrix is known then you can compute V 1 and V 2 okay. The other one is voltage is given what be the current we call them y parameters when the voltages are given and you are asked to determine the currents, you take the help of the y parameters or short circuit parameters, admittance parameters, there are different names and the third one is if you are given in a mixed mode that is a voltage and current at the receiving end, say at Jamshedpur and you have to calculate the voltage and current at Kharagpur all right.

So if you are given V 2, I 2 what will be V 1, I 1 or vice versa. So V 1, I 1 if it is to be calculated from V 2, I 2, mind you this sign V 2, I 2 then these parameters are known as transmission parameters or A, B, C, D parameters, transmission parameters or A, B, C, D parameters. For transmission at one side you are putting voltage and current at the other end you are receiving V 2 and I 2 all right. So it is from one end to the other end you see V 1, V 2, I 1, I 2 these are in a mixed mode in a sense that voltage of this, voltage of that that means both the terminals the variables at both the terminals were used as inputs as well as a outputs, if this is given as the input we are given I 1 and I 2 but at 2 different nodes okay, transmission means as if you are transmitting power from one end to the other you are computing from this side, if you are knowing V 1, I 1 what will be V 2, I 2 or if you are receiving V 2, I 2, what will be V 1, I 1 okay.

So now we shall take up 1 by 1, the properties of these are how to compute these quantities, this is known as driving point impedance at terminal 1, 1 dashed, this is known as transfer impedance, this is also transfer impedance and this is driving point impedance at terminal 2, 2 dashed okay. Similarly, this one is driving point admittance or short circuit admittance, this is transfer admittance, this is also driving point admittance A, B, C, D they are known as A, B, C, D parameters, what will be A, what will be B, we will see A is basically a voltage gain okay or voltage ratio similarly, D is a current ratio of course with a negative sign similarly, B represents the impedance.

We will also try to establish the relations between different parameters sides what will be the relation between given Z's can you calculate Y's or A, B, C, D or given A, B, C, D can you calculate Y or Z. So inter dependence of different the other relationship between different sets of parameter that would be our next task for that to start with we will be discussing about the determination of these parameters.

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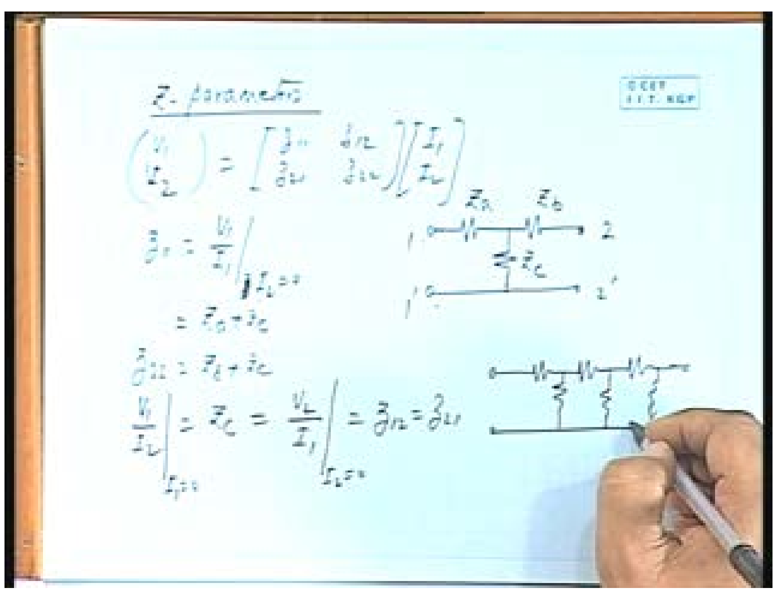

Let us see first the Z parameters or open circuit parameters, V 1, I 1 sorry V 1, V 2 we wrote Z 11, Z 12, Z 1, Z 22, I 1, I 2, now you can see what will be Z 11, Z 11, when I 2 is equal to 0, it is a ratio of V 1 by I 1 okay. So V 1 by I 1 when sorry I 2 is 0 okay, let us take a very simple example suppose, you have I will write a general impedance Za, Zb, Zc, 1, 1 dashed, 2, 2 dashed, a simple T network okay.

Now if I want to make I 2 equal to 0, there is no current through this, so this has to be kept open so that 8 is why it is known as open circuit parameters all right. So if I keep it open and measure the ratio V 1 by I 1 how much is it yes, it will be Za plus Zc, Za plus Zc. Similarly, Z 22, Zb plus Zc I hope is understood and then what would be Z 12, it is V 1 by I 2 when I 1 is 0 that means that means I keep it open, I do not send any current through this keep it open and then what is the voltage V 1, what is the voltage obtained here that divided by this current, so I send ampere current inside through this, how much is the voltage here, 1 into Zc, so V 1 by I 2 when I 2 is 1 ampere it will be Zc into 1 all right whenever you want to compute any ratio put the denominator as 1 and then see what will be they get, so if I 2 is 1, V 1 is equal to Zc, so Zc.

So that means if I have a T arrangement or a star network like this. So Za plus the shunt element will be the impedance in from this side open the driving point impedance or Z 11 similarly, Z 22 will be this impedance plus the shunt element and Z 12 will be this shunt element. So will be Z 1 you can see with the same logic if I want to compute Z 21, it will be V 2 by I 1, so I excite it from this side sorry, I excite it from this side I pass a current I 1 and measure the voltage here I 2 is may 0, so I measure the voltage here. So that will also be Zc so this is also equal to V 2 by I 1, should I write like this V 1 by I 2 under what condition I 1 equal to 0 similarly, this one I 2 equal to 0 thank you, so that will be equal to Z 12 or Z 21 is it all right.

Now any network, if you are given any network like this there could have been many more connections may be a connection like this okay. I can always reduce it by repeated startled conversions to an equivalent star okay say this phi network, I could have converted to a star all right and then again add with the elements here, this one and then again a delta. So delta to star conversions if I make a repeated conversions, I can finally bring it to this once you know these 3 elements then straight away this plus, this is Z 11, this plus, this is Z 22 and this one is Z 12 or Z 21 all right, It is a symmetric matrix. For linear lumped finite bilateral network, bilateral means impedance in from this side and impedance in this side will be identical for any element okay if I put a diode then it no more remains a bilateral okay.

So if you do not have any diode if you have only passive elements, only passive elements then you will find Z 12 is equal to Z 21 and it is a symmetric matrix okay. You can extend this concept of representing voltage in terms of the current that is voltage vector in terms of the current vector in a multiport network.

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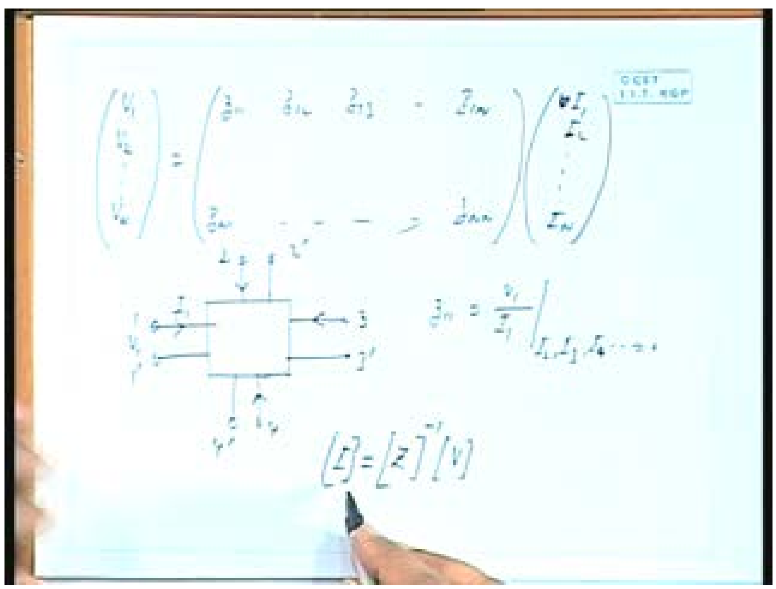

In a multiport network therefore we will have V 1, V 2, V n, n number of ports and this will be Z 11, Z 12, Z 13 to Z 1n similarly, Z n1 up to Z nn, I 1, I 2 and I n, okay it will be a network like this. I am showing only 4 ports here, there can be many more ports that means you are feeding power all right these are voltages and corresponding currents similarly say 1, 1 dashed, 2, 2 dashed, 3, 3 dashed and so on.

So 4, 4 dashed and so on, so if I have a multiport network like this to compute these values I have to keep only one of the variables here active, others must be made 0. So Z 11 in this case we shall be defining as V 1 by I 1 where I 2, I 3, I 4 all of them are made 0 that means all the terminals are kept open. So you take one at a time these currents and rest of them are made 0 and you evaluate these parameters okay. Next we come to okay just one more minute from here you can write I in terms of V also, I therefore will be if I am writing in a matrix form Z inverse V matrix V, matrix means it is a vector here will be equal to I okay.

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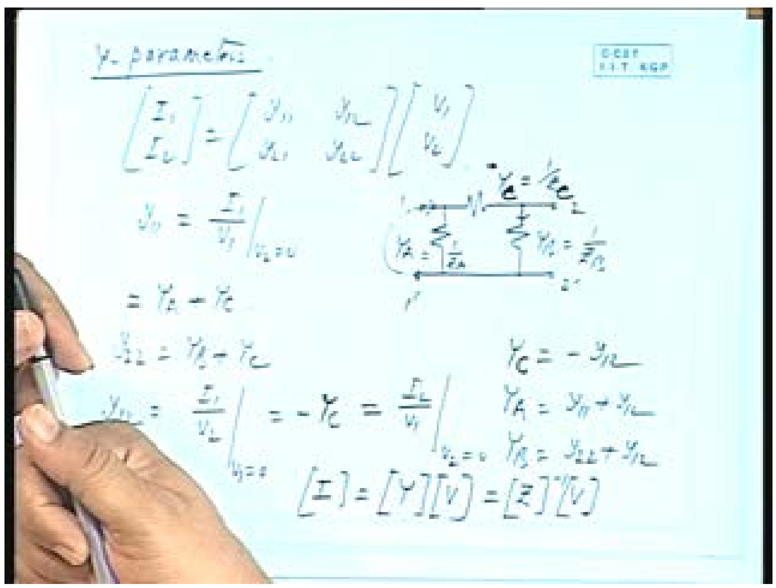

Suppose, we write in the Y parameters in terms of the Y parameters that is again will come back to 2 port network I 1 and I 2, we write in terms of Y 11, Y 12, Y 21, Y 22 into V 1, V 2. Now the voltages are given if you have given the voltages V 1 and V 2 what will be the currents I 1 and I 2 that get that current set will get fixed by the admittance parameters, how much would be what will be the expressions for Y 11, it will be I 1 by V 1 under what condition V 2 equal to 0 is it same as V 1 by I 1, Z 11 inverse I know, Z 11 was computed when the circuit was kept open now you are keeping it short V 20 means short circuited.

So let us take once again that 2 port elements, we could have, we had obtained finally after reduction T elements set Za, Zb, Zc okay. Now let us take a phi element set or a delta form that is we can always write either in terms of a star or a delta form. So let this be represented by their corresponding admittances that is I write this as Ya which is equal to 1 by Za, if this is Za, this Za has got nothing to do with the earlier Za, earlier I had written small Za, Zb, Z small a, Z small b, Z small c okay. So here I am writing all right let me put this as c that will be better Zc similarly, this one as YA which is 1 by Z A whatever is the impedance inverse of that Y B which is nothing but 1 by Z B so if I make V 2 equal to 0, V 2 is equal to 0 that means I short circuit this then I send a current here measure the voltage here all right.

So for any such ratio you make the denominator 1 that means I apply 1 volt supply voltage here and measure the current I 1 after shorting this. So how much is it? It is a admittance in from 1, 1 dashed under this condition, so it is 2 parallel elements Y A and Y C okay, is it not Z A and Z C are in parallel. So you add their admittances Y A plus Y C very good similarly, Y 22 will be Y B plus Y C when I am shorting this side what about Y 12, what about Y 12, how do you measure Y 12, Y 12 is I 1 by V 2 when V 1 is 0. So I short circuit this and then measure the current here when I am applying a voltage V 2.

So Y 12 is I 1 by V2, I 1 by V 2 when V 1 is equal to 0 and how much is that by convention I 1 is positive when it is flowing in this direction. Now when I am shorting this and applying a voltage here, there will be a current that will be flowing like this. This current does not affect this, does it this current is independent of this side, I am measuring only this current and since this is short. So this is redundant there is no current flow through this all the currents will be flowing through this, so the currents flowing through this side will be through Y C and then through this 0, 0 impedance. So how much is the total impedance Y C, only Y C what about sign because the current is flowing in the opposite direction, so it will be minus Y C okay.

Now if you are given this Y parameters, there is a black box given to you, I have giving you 2 ports, 4 terminals and I ask you to perform this short circuit test that is you short circuit 1 side 2, 2 dashed make a measurement from this side, make the measurement of the current on the other side, voltage from this side, voltage and current at this end that is all that is you measure V, V 1, I 1, I 2 again excite the other side, short circuit this side 1, 1 dash apply a voltage V 2, V 2, I 2 and I 1 okay.

So you will get all the 4 quantities, this is also I 2 by V 1 by the same logic, when V 2 is 0, when I short circuiting this applying a voltage and measuring this current is it all right, if you are given these parameters but inside I do not know what it is, it can be number of elements inter connected okay. Now what would be the equivalent parameter values Y A, Y B, Y C, it is very simple whatever you calculated as Y 12 take the negative value of that will be Y C, is it not?

So the elements values are Y C is equal to minus Y 12, have you understood the question? The question is, if you have already evaluated Y 11, Y 12, Y 21, Y 22, what would be the equivalent delta network, what be the equivalent phi network elements I will stated. Let Y C is equal to minus Y 12 and then Y A, how much is Y A, it is Y 11 minus Y C and minus Y C means Y 12. So Y 11 plus Y 12 similarly, Y B will be Y 22 plus Y 12 is it not now for this also you can generalize you can write I 1, I 2 up to. In this can be an n by n matrix like the earlier one for an n port network and you will have V 1, V 2 up to V n okay.

So matrix Y, I could have written vector I is equal to matrix Y into vector V. So Y is nothing but Z inverse, so elements of Y can also be computed once you know the input circuit parameters. You can calculate the short circuit parameters, is it all right? So we have seen that for the Z parameters or open circuit parameters representation like this T representation is very convenient, the element values are directly related to the Z parameters similarly, if you are given the Y parameters or if you are asked to calculate Y parameters take the network in the phi form then from the values of the impedances directly, we can calculate the parameters, is it all right. Thank you very much, we will continue with this in our next class.

Good afternoon friends, we shall continue our discussions on 2 port network. In the last class, we have established relations between voltages and currents in terms of Y parameters and Z parameters. Let us take a simple example, a resistive network say these are the values given 5 ohms, 10 ohms, 10 ohms, 20 ohms and 20 ohms, this is just an arbitrary set of values I have taken, what would be the Z parameters say Z 11, it is a voltage at this point, at this port divided by the current, when this is kept open. So Z 11 is 5 ohms plus 10 ohms in parallel with 10 plus 20, 30.

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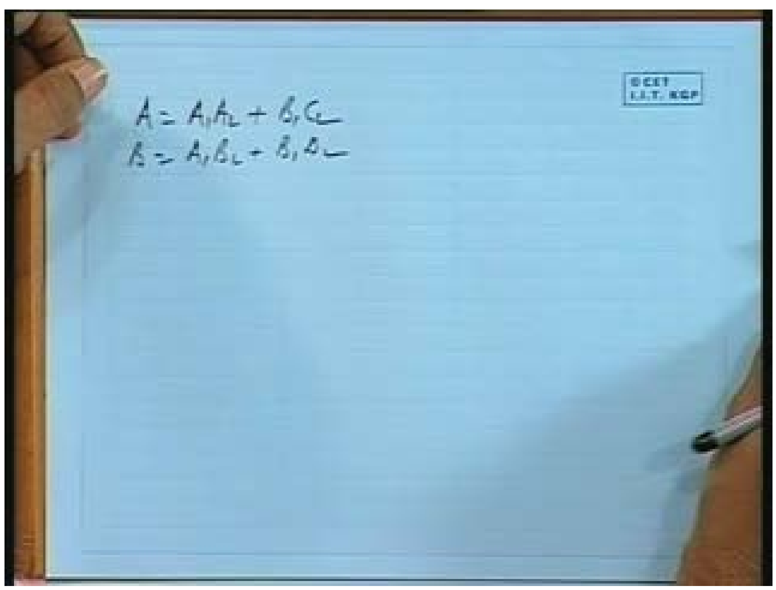

So it would be 10 into 30 by 10 plus 30, so that gives me 300 by 47.5 plus 5. So it gives me 12.5 ohms okay similarly, what would be Z 22, it is the impedance in from this side when this is kept open, see it is 20 plus 20 in parallel with 20. So that is 10, 30 ohms I should write this ohms this also in ohms, okay Z 12 if you want to determine, it would be V 1 by I 2, when I 1 is 0. So if I keep it open send a current here, how much is the voltage dropped here that means how much is the voltage here, see this is kept open this voltage is this voltage is kept open and I am forcing in a voltage from this end.

So it is V, A 1, A 2 plus B 1, C 2, B will be, B will be, so this multiplied by this A 1, A 2 plus B 1, C 2 then this multiplied by this, so A 1, B 2 plus B 1, D 2, A 1, B 2 plus B 1, D 2, mind you this co-efficient this element A is a ratio of 2 voltages. So it is a dimensionless constant, dimensionless parameter okay. Now does it will have a magnitude does it have an angle it may have an angle it is a, if the impedances are complex normally in a transmission line we have RLC. So impedances are in a complex form so the ratio can be a complex constant dimensionless but it may have an angle.

So here also we find it is the product of 2 dimensionless quantities, it is this B 1, what was the dimension of B 1, say B, B is the ratio between voltage and current that is impedance and C is current and voltage that is admittance. So B and C product will also be a dimensionless quantity, one is more the other is ohm. So this confirms to the dimension of this similarly, B impedance this one is impedance multiplied by constant, this also impedance multiplied by constant because D has a dimension of it does not have any dimension it is a ratio of 2 currents.

So similarly C and D, we can write. So we will stop here for today and next time we will take up, we will discuss something about hybrid parameters and then we will take up some numerical problems. So the next class will be a tutorial class on whatever we have covered so far, we will have some problems okay. Thank you very much.