Electromagnetic compatibility, EMC
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Module 4.5
Crosstalk
Interaction of electromagnetic fields with electrical circuits
Exercises

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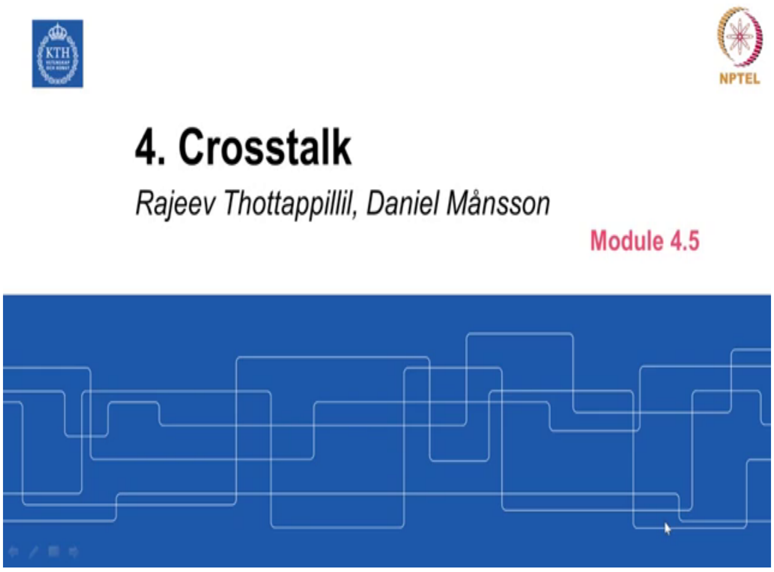

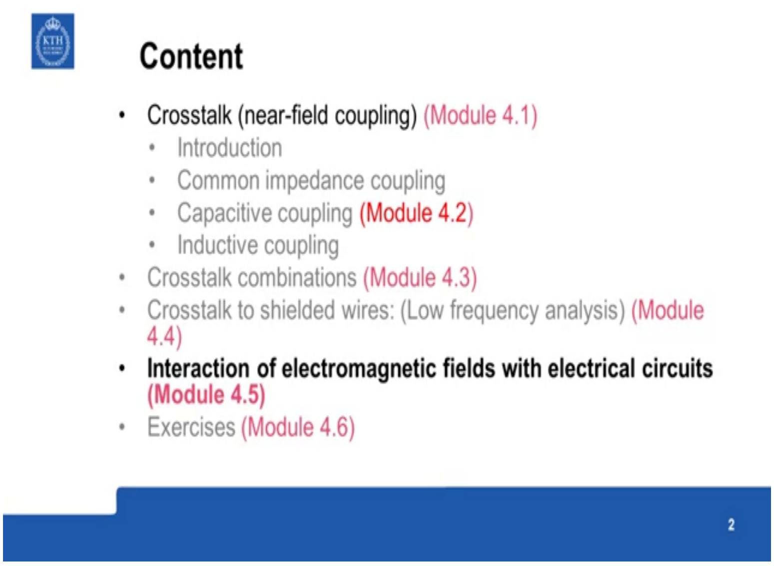

Crosstalk module 4.5, in this module we will look at electromagnetic field interaction with small electrical circuits.

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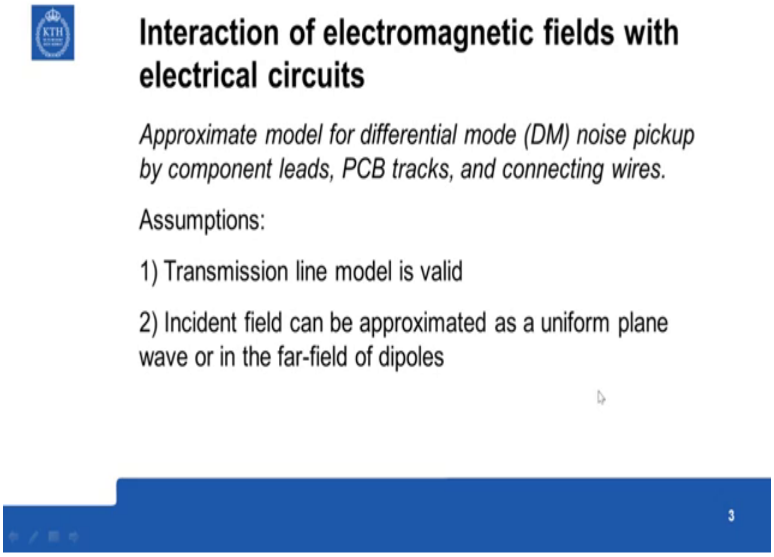

What we will is approximate model for differential mode noise pickup by component leads, PCB tracks and connecting wires. The assumptions are the transmission line model is valid and incident field can be approximated as a uniform plane wave or in the far field of dipoles, so we are not talking about near field coupling in these, even though as you will see, the model that we come up is quite similar to the model that we have derived for near field inductive and capacitive coupling but in this case it will be action of magnetic field and electric field.

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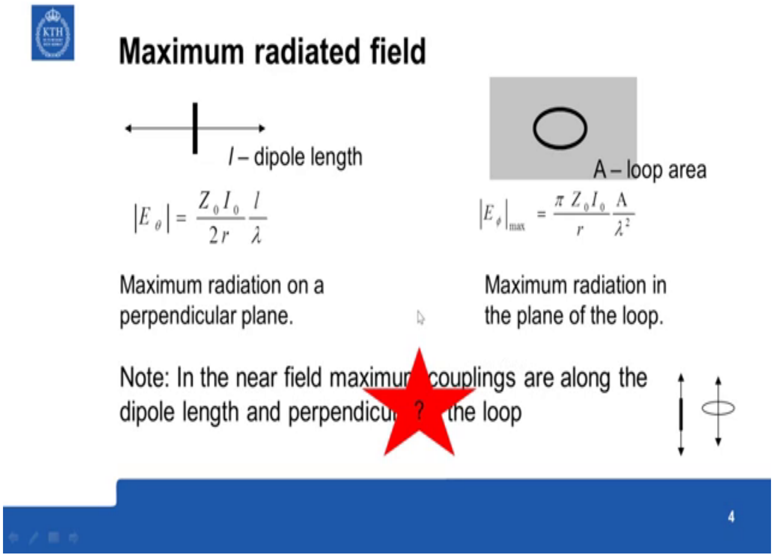

Previously we are seeing that, we can find maximum radiated field from magnetic dipole and magnetic loop and maximum radiation is in a plane perpendicular to the dipole and here the maximum radiation for a loop is, in the plane of the loop, however in the near field maximum couplings are along the dipole length and perpendicular to the loop.

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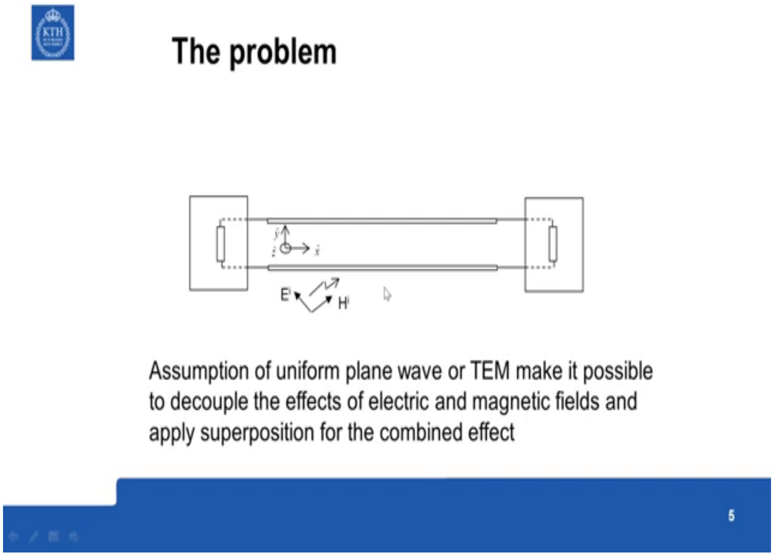

So the problem that we have is somewhat different from the previous one, so here assumed that you have two wires, it can be component lead or PCB tracks with some loads at the end and you have a TEM wave incident transverse into magnetic wave in which electric field and magnetic field are in a plane perpendicular to the direction of propagation, now the cornices system is defined here X axis and Y axis and Z coming out of the paper, so since it is TEM we can separate the effect of magnetic field and electric field, then combine those effects by applying the superposition theorem.

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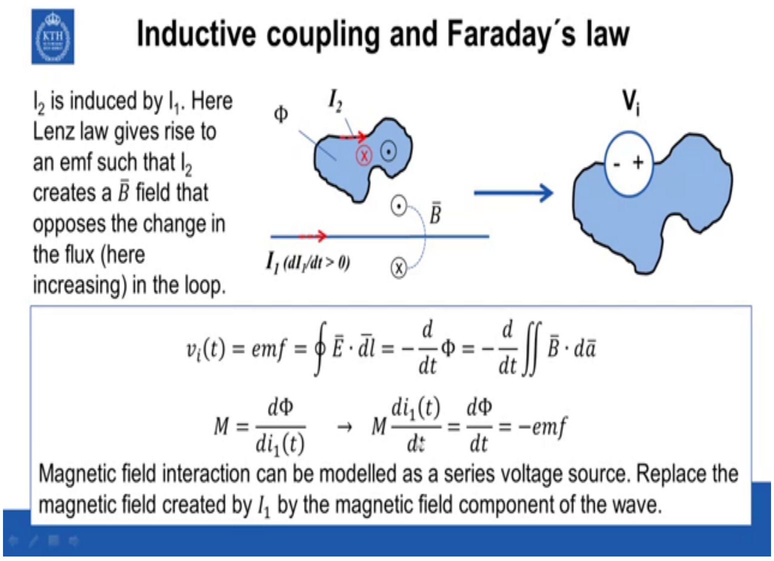

Now let us see the inductive coupling in faradays law that we have seen before, now where we found that EMF by the action of a magnetic field is given by the close line Intergraph E dot DL and from this we have come up with the model for magnetic field interaction as a series voltage source, however in capacitating this model we use the circuit parameter M because we are in the near field, so we are talking of mutual inductance and all, whereas in the problem that we have now, we will be replacing the magnetic field created by this current I1 by the magnetic field component of the wave of that EM wave and we will not be using the circuit parameter M.

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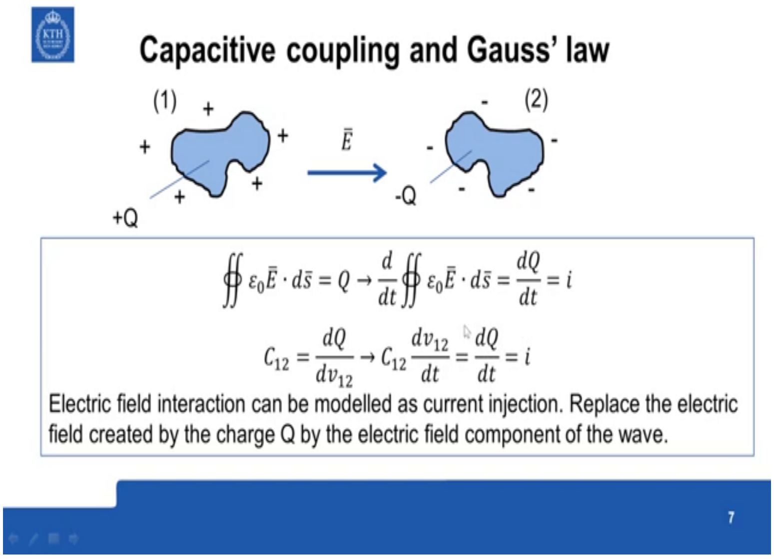

Similarly for capacitive coupling and using Gauss law, we found that the surface integral of the total flux coming out is equal to the charge and close and from there and from the definition of capacitance, we have come up with a model for electric field interaction as current injection, however here we will not use these coupling capacitors instead we will use the electric field component of the wave for finding the model.

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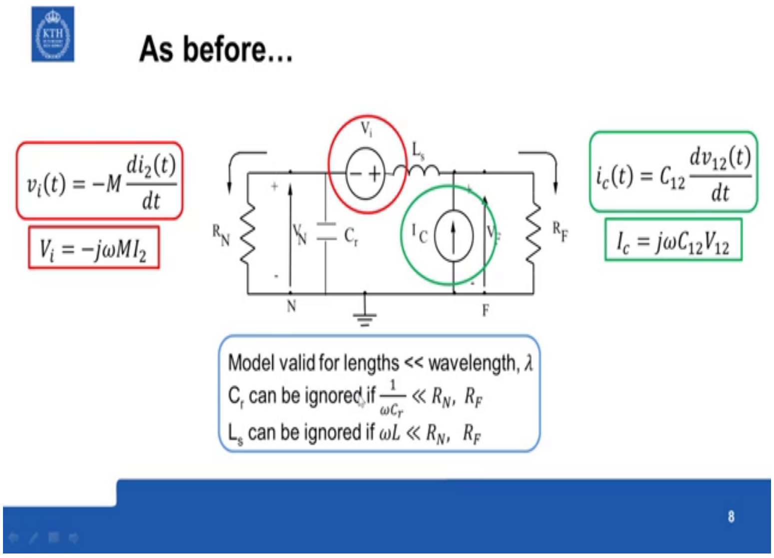

So this is just a recap of what we have seen before for the near field, so the strategy is again the model, the magnetic field interaction by a voltage source but without involving the mutual inductance and modelling the electric field interaction by a current source without involving the coupling capacitors and as before CR and LS series inductance and parallel capacitors can been neglected when these conditions are true, when impedance compare to N impedance are meeting certain criteria and also we will not use near field and far field anymore because it will not make any sense, there is no near, sorry near end and far end in the problem that we are investigating now.

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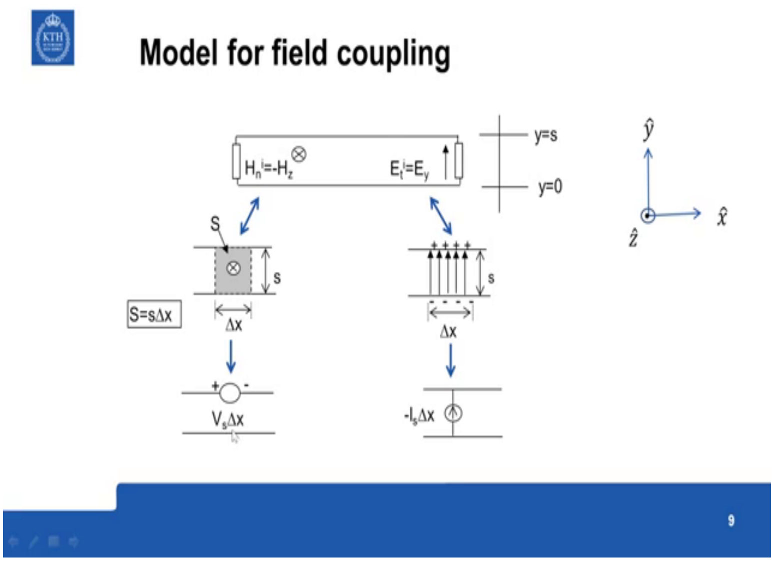

So this is the diagram meant for model, so you have a small component lead or transmission line, the some loads, so the incident wave and it is separated by a distance S, so it is in the Y direction, Y equal to 0 and small S, so let the magnetic field be going into the plane of the paper incident field, so that will be equal to because of this cornices system minus HZ component and incident electric field is in the Y direction, the transverse field, so the normal component in the magnetic field, you take a small section of the line delta X is the X coordinate, so small section of delta X, so you have an area enclosed, so the magnetic field is going through this area, so this will create a voltage from faradays law.

So that voltage will drive a current in such a way that it should create a flux oppose it to this, so the direction of the voltage source is like this, so this voltage source we write as, if VS is unique length induced emf, then we multiplied it by delta X because it is proportional to this delta X, so VS delta X is small elmendor voltage source, total surface area is given by this small S by delta X, so similarly electric field interaction can be model like this, suppose due to this action you have a charge separation and integral of this electric field will give you a voltage difference, now this voltage difference is in series with this circuit capacitance, these are not couplings capacitance, so it is a capacitance between these two lines, so that can be converted into a current source IS per unique length and multiplied by delta X you will get with this elmendor current source, so this is the model for electric field interactions, so we will find how we can find this IS and VX in the later graph.

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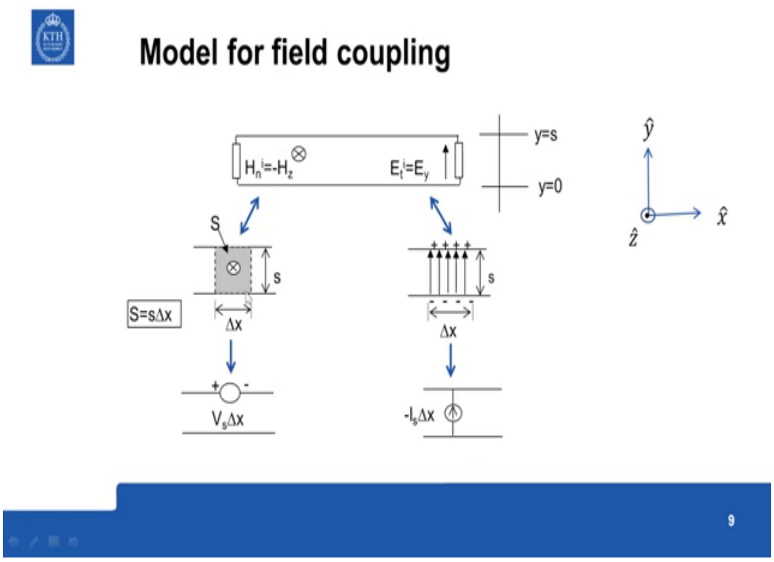

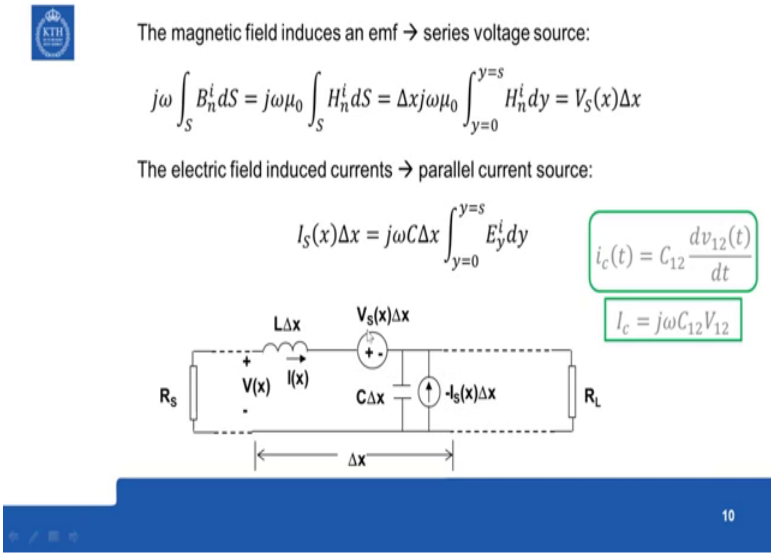

So the magnetic field induces an emf a series voltage source, so surface integral of weight of change of the flux, so if you take this small elmendor area and integrate around this area you get an expression like this BM is the incident flux density and integrating over that small surface, that small surface area you can get it as delta X into small S, if H is uniform across but otherwise we can sprightly write it as an integral form, so J omega mu 0 surface integral of H DS, now DS is equal to delta X into delta Y, delta Y in this direction, so we are assuming that the field is not uniform here, so we are taking a generic case that is why we are doing this integral, so delta X then SY equal to 0 to S, you are integrating HN for is Y.

So this would be equal to voltage times delta X, so J omega meu 0 integrate 0 to S, HDY is the voltage source, then delta X, nor electric field induced currents, you know that will be the parallel current source, so that is given by, C times rate of change of voltage, so it is this equation we are writing, so instead of coupling capacitance it is this capacitance that we have here, so that is the only difference, so it is quite similar even though an important difference is that, this C here is the capacitance between these two wires and not the coupling capacitance as in the previous case, so since this is a positive and this is negative but we assume the direction of the current upward if it is a negative sign in front, so this completes our model, C delta X, L delta X in the sources, similarly you can have several elements like that, so in each of this element VS and IS can be slightly different depending upon how the voltage and current is varying around the line, so this is the generic case.

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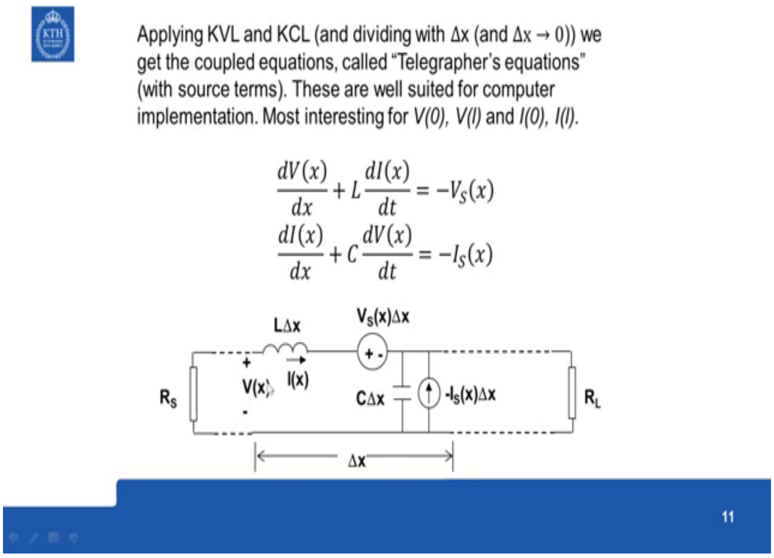

Then we can apply Kirchhoffs voltage law and Kirchhoffs current law and dividing with delta X and delta X is to 0 then you get the differential forms and this is what, this called telegraphs equations we can drive this, this equivalence circuit, so however we are mostly interested in what happens at the two ends, parallel what happens in between.

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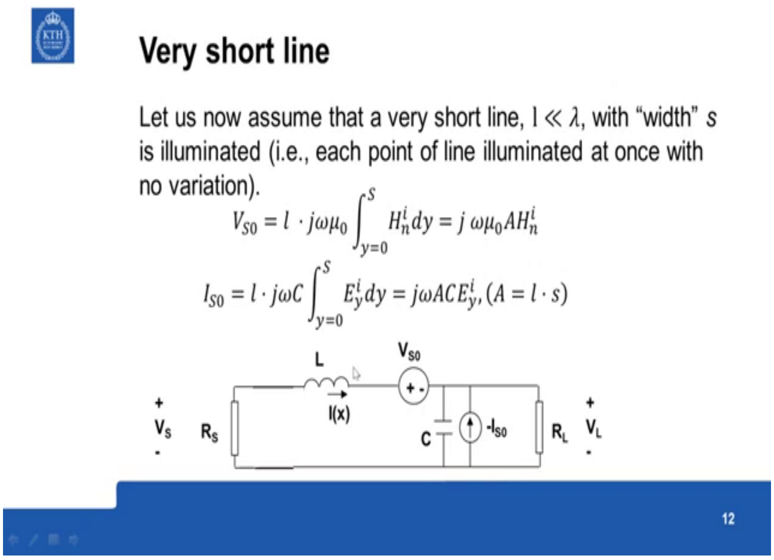

So will take a very specific case of short line that is what mostly we will be dealing with and short line will be in which the length of the line is fraction of a wavelength, so we can neglect all the variation of the field around this small transmission line in that case, the whole width S is illuminated and there is no variation, so you can replace this integral by now area A which is given by the length of the line L times the width of the line S, so voltage sources is given by J omega meu 0 area times HN, so this will give the meu 0 HN will be giving you the complete flux and J omega and this flux 5 will give you rate of change of flux in timed of the.

Similarly the current, connection current is L, total length times J omega C into integral of 0 to S EYDY, so since EY is uniform, you replace this by L times S, small S for the width of the line then you get A here and C, A equal to L in L times S, so we got the values of both sources.

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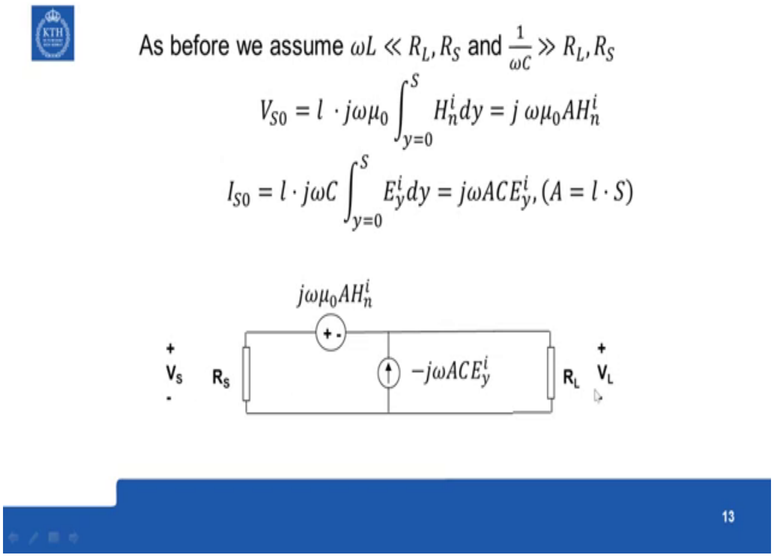

So as before if we say that omega L is for less than the terminal impedances and 1 by omega C is far greater than the terminal impedances, we can neglect those capacitance and inductance and now we have just two sources one representing magnetic field interaction and negative from interaction and the two loads over there and we are interested in VS voltage across this and voltage across this.

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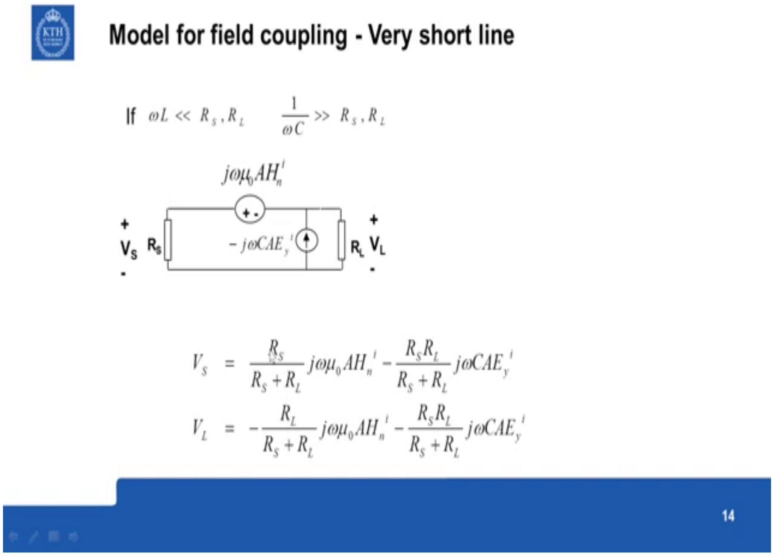

So we saw for VS that will be, now we can apply superposition theorem, first this source, so total current is this voltage divided by some of these currents, this voltage is divided by some of the, sorry some of the resistances multiplied by RS will give you this voltage, due to this source, now from the other source where the current is divided across, current through the these branches RL divided by RS plus RL, then the source minus J omega CAEY multiplied by RS to give this voltage, similarly on this side this will be negative and this will remain the same, so as before you can see that for the path related to magnetic field on both ends, induced emf is the same, whereas here it is of opposite direction and of different value that from the magnetic field, so the general behaviour is very similar to the near field crosstalk in terms of characteristic of the voltages at both ends, so that is end of that module. Thank you.