Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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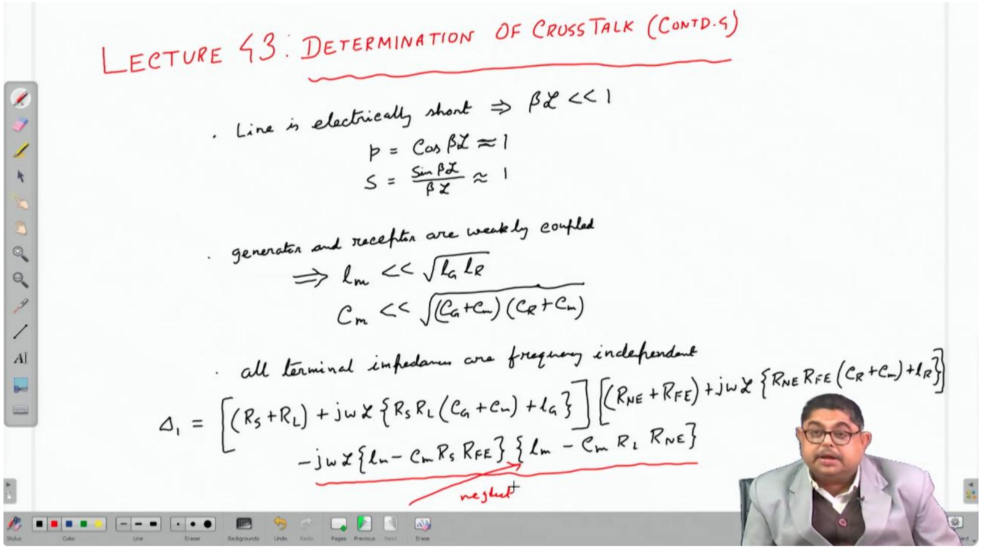
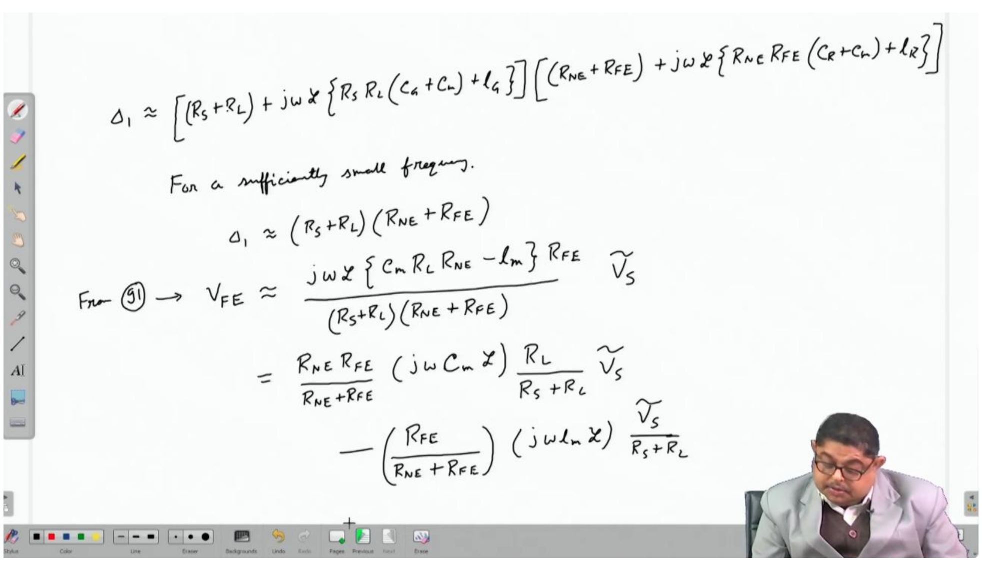
Lecture 43: Determination of Crosstalk (continued)

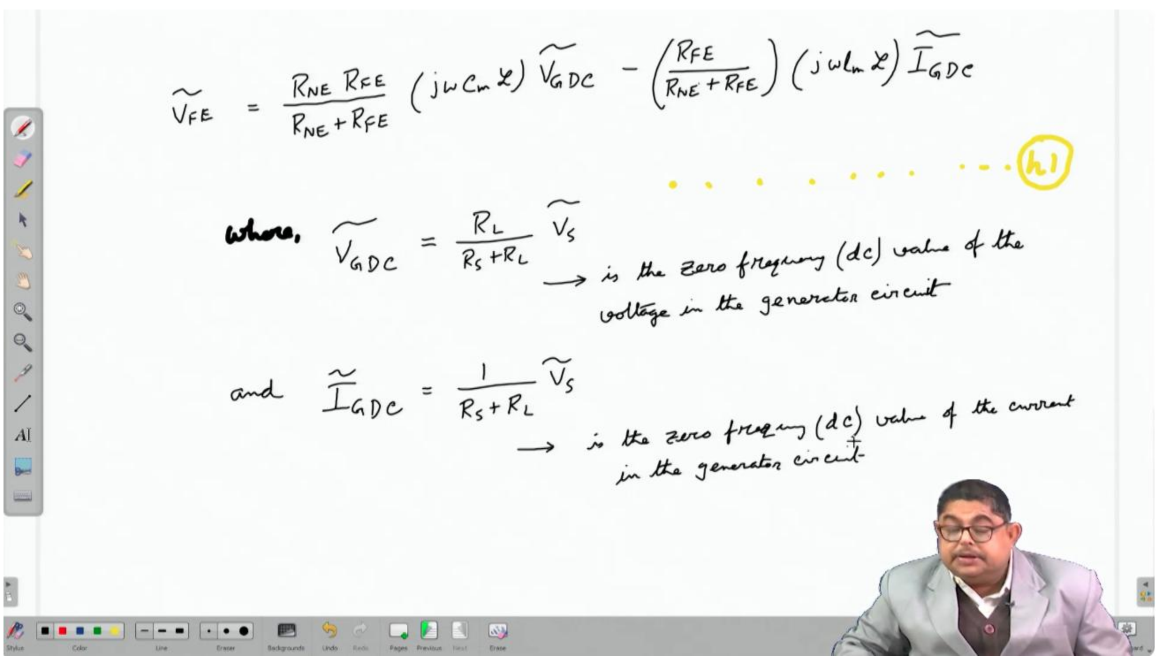
Welcome to the lecture of the course on EMI EMC and Signal Integrity Principles Techniques and Applications. We are continuing our discussion on crosstalk. So, we now make some simplification. The simplification is that the line is electrically short. So, this means that the line is electrically is much much less than 1. So, if we do that beta l is the electrical length of the line. So, that is much smaller than 1, then p is cos beta l. So, that becomes 1 and s is sin beta l sorry these are all that also becomes 1 because this is a sinc function. So, this sinc function at very small value is almost like 1. So, this the second that is weakly coupled. So, this weakly coupled means through l m and c m. So, this means l m is much much less than root over l g l r and c m is also much much less than root over c g plus c m into c r plus c m. So, all terminal impedances are the independent. Actually these assumptions we have already taken because the terminal impedances R S, R L, R NE, R FE all we have made resistances. The integration is that all terminal impedances are resistance. Already we have taken that in the model we have not taken any reactive component in the terminal impedances. So, for this nothing is a. So, now let us see what is happening to our for these three conditions what is happening to delta 1. So, delta 1 if you recall from equation g 1 delta 1 is R S plus R L plus j omega l S actually that S I am now removing because it is 1 p also I have removed. So, j omega l then R S, R L into c g plus c m plus l g. It is continuing into minus g g omega l then l m minus c m R S, R FE. So, this is the delta 1. So, delta 1 into l m minus c m R L, R FE. This is delta 1 with p and S is equal to 1. Now you see that since l m where is l m this term you see l m is much less than l g l r. So, this term similarly that means l m is much less than l g l r. So, this terms you see so that means this whole term this term due to l m it will be twice multiplied similarly c m will be multiplied also l m c m will be multiplied. So, this term can be neglected due to this weakly coupled condition.



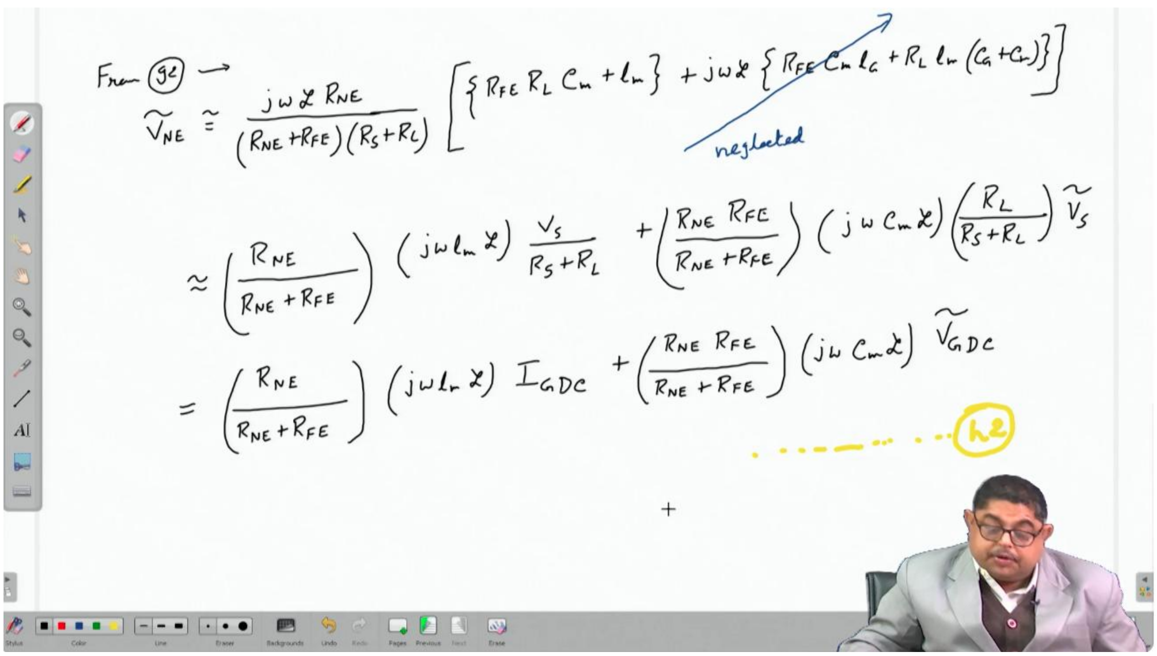
So, delta 1 is R S plus R L plus j omega l R S, R L into c m plus l g l. So, delta 1 is c g plus c m plus l g into R ME plus l g into R FE. So, delta 1 is R AP plus j omega l R NE, R AP plus c m plus l g l. So, this is delta 1 plus l g l plus l g l. Now, again you see that omega l so this we have assumed very electrical short line. So, this whole j omega l terms they can be neglected compared to R S, R L. So, for a sufficiently small frequency so we can say that for a sufficiently small frequency delta 1 is almost R S plus R L into R NE plus R AP. So, with our three assumptions in the model we are getting delta 1 like this. So, from g 1 we will get an expression for V FE what is that V FE we can say V it looks odd V FE is j omega l c m R L R NE plus l g l. So, this is equal to V FE minus l m into R AP by R S plus R L into R NE plus R AP into R ME. So, this one we can now write like this that R ME, R AP by R ME plus R L by R ME plus R AP into j omega l. Because that let me bring c m c m into l R L by R NE plus l g l. So, this is equal to V FE by R S plus R L V S minus R AP by R NE plus R FE j omega l.



So, this is equal to V FE by R ME plus l g l. This is equal to R NE R fe by R NE plus R FE j omega c m l V S plus l g l. So, this is equal to V FE by R FE j d c minus R AP by R ME plus R AP j omega l m l I g l. So, this is equal to V FE by R ME plus g d c. And this is an important equation I am calling h1 as V FE. Now, this shows that V FE is contributed by one is by the c m another is by l m. And I have defined two new terms V g d c and I g d c. So, V g d c is V d d c is R L by R S plus R L into V S. And what is it? It is the V g d c is the zero frequency that means, the V g d c value of the voltage in the generator. At zero frequency d c you see the there are no coupling exist between the generator and the receptor. So, the circuit is simply in the circuit there are R S and R L. So, V S is the excitation. So, the current in the circuit is V S by R L R S plus R L and V g d c the voltage that is happening that is at the load end it is in the current into R L. Similarly, I g d c is 1 by R S plus R L into V S. So, this is the zero frequency d c value of the current in the generator. So, this is about V f e and you see that one part is contributed by the mutual capacitance, the another part is contributed by the mutual inductance.



Similarly, we can do for V n e. So, from equation g 2 we can find V n e is J omega L R n e by R L. So, this is J omega L R n e plus R a p into R S plus R L R a p R L c m into R L into R S plus L m plus J omega L R a p c m L g plus R L L m c g plus R L L g into R S plus R L m plus c m. Now, again with that condition that the line is electrically short and the receptor is weakly coupled to generator that means, c m and L m are very small compared to L g and other a things. So, we can say that this one can be neglected with respect to the first term. So, that gives us the R n e by R n e plus R a p J omega L m L V s by R S plus R L plus R a p J omega L R a p plus R L m L V s by R S plus R L m L V s by R S plus R L m L V s by R S plus R L into V s. So, this is the expression for the near field crosstalk and I am calling it h 2. So, we can see that to both V n e and V f e there are two contributions to each of them a term due to the mutual inductance L m that is called induction coupling contribution and a term due to the mutual capacitance c m that is called capacity coupling contributions and the actual crosstalk voltages they are superposition of the two.



So, we can draw the circuit that receptor circuit that is we have a R n e. So, this is my R n e this is my V n e then from here I r 0 is going and then the I r 0 is going and then the I r 0 is going. So, I am going to write the capacitive coupling terms that comes as a current source J omega c m L V G d c actually d B d t. So, c into d B d t. So, that is a current source and for inductive coupling I have a voltage source J omega L V G d c. So, it is L di d t and this is my R f e and the current that leaves is I r L and this voltage is my V f e and I can say that this is my total length and you see now we can see that for V f e we have written I r L into R f e and V n e you see that V n e is minus I r 0 R n e you apply the a thing that if I assume that this is there this is a drop. So, V n e plus R n e I r 0 is equal to 0. So, from that V n e is equal to minus I r L that is what we have used you can see that ah this one V n e is equal to minus R n e I r 0. So, this equivalent circuit get this. Now, so what are the mutual relation of this inductive coupling and capacitive coupling and the transfer function of the two cases we will see ah in the next class. So, this is an important thing that every cross talk voltage that has contribution one from the inductive coupling another from the capacitive coupling. Thank you.