Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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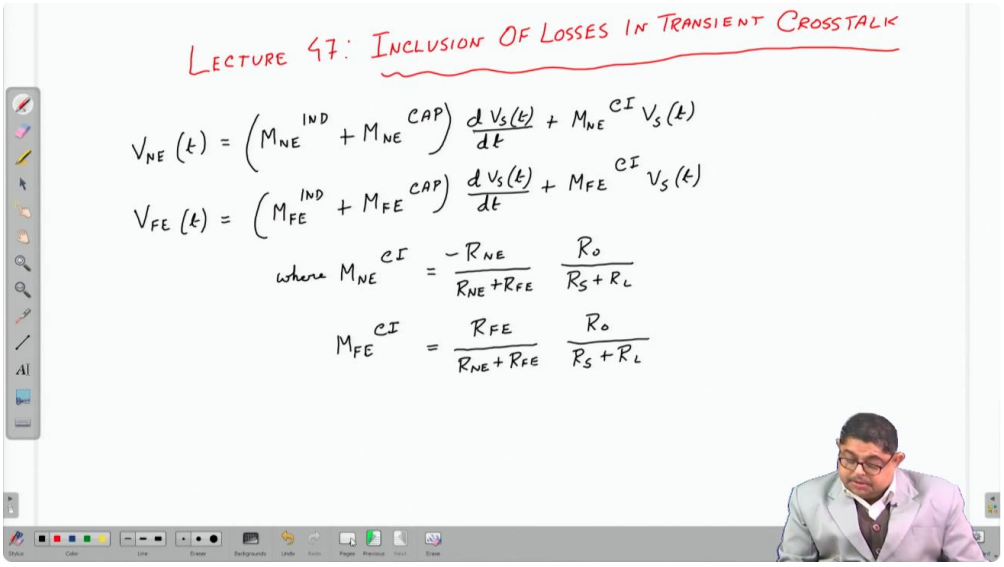
Week :10
Lecture 47: Inclusion of Losses in Transient Crosstalk

Welcome to the lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Applications. We had discussed transient crosstalk in the last class that was a lossless model now we refine our model and include losses. So, that means, the resistance of the line conductors are included as a crosstalk contribution. Thank you. Resistance so, no derivative it is simply the multiplication of voltage. So, where the MNE ci will be equal to these things we have already found out for frequency domain. So, the same applies here.



So, now with an example I will explain. So, consider the previous problem lossless case in that include losses. So, include losses in the previous problem that means, this problem that this is the problem. Now you assume that the lines are not perfect conductors they are have a loss and that loss things are we have already found out. So, in that earlier problem that in that when we did common impedance coupling for in

frequency domain. So, we said that the per unit length resistance is r 0 was 0.194 ohms per meter the line length is these. So, lumped resistance capital R 0 was 0.92 ohm. So, that we will take so, that means, we can write MNE ci is 9.21 into 10 to the power minus 3 and the same is for MFE ci for this problem because RNE, RFE are 0.9. So, what is MNE V st that will be 9.21 into 10 to the power minus 3 into V st is 2.5 volt where at t is equal to tau r at t is equal to 0 it is 0 it is linearly rising. So, these value is 23.01 milli volt. So, we can now draw the graph of V this will be ci Vnet.

So, we have seen in the previous case it is you look at here 75 milli volt here due to inductive and capacitive coupling it is staying stay flat up to 400 nanosecond, but here that would not be the case because the MNE ci V st that is changing from 0 to 23.01 milli volt. So, let me mark various points 75 of this is in milli volt let us say 75 then. So, at t is equal to 0 there is no contribution from these. So, I can say that is equal to 0 at t is equal to 0.So, 75 so, it will start the graph from 75, but when it will reach tau r there is an additional 23 milli volt. So, 75 plus 23 is 98. So, there will be a 98 also here. So, and this side let me mark that there will be 400. So, let me do one thing this is make it nanosecond.

So, 400 then it will be 2 4 6 0 0 nanosecond then there will be 2 5 0 0 0 nanosecond there will be 5 0 0 0 0 nanosecond. So, and similarly this side what that I will do later first let me draw these. So, at this point it will go here. So, it is like this due to the loss this is going here then at 400 millisecond the capacity after 400 millisecond the capacity and inductive coupling contributions they are 0 as you see they are 0, but common impedance coupling is there. So, common impedance coupling will come to a value 23 milli volt. So, that means, it will it will come to 23 milli volt then it will stay here there is no contribution from capacity band a coupling then at again after 24.6 micro second there is the fall time starts. So, capacity band inductive coupling will give their contribution. So, that time the you see the previous graph they are going to minus 75 milli volt, but 23 milli volt is same. So, 23 minus 75 will be there. So, that is minus 52. So, let me mark somewhere minus 52 and it will continue to minus 75. So that means, this curve will come to minus 52 here then the capacitive coupling contribution is there and at the end it is the after fall time V st at 25 micro second that goes to 0 that means, common impedance coupling goes to 0 again at t is equal to tau. So, this value is minus 75. So, roughly it will come to minus 75 here then the capacity band inductive coupling goes up because there is no change in the V st. So, they are coming here and then again from 50 it is going up. So, that time it is again 75 milli volt this is roughly 75 from there it goes up so like this. So, this is that V n it is graph.

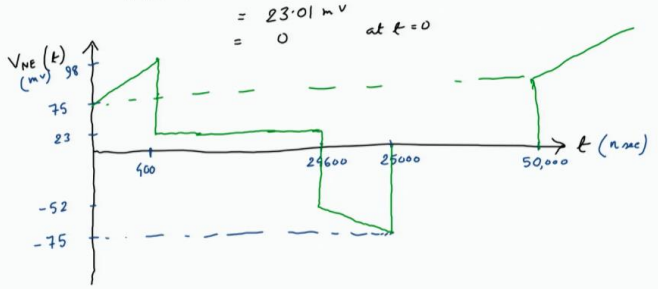
Include losses in the previous problem

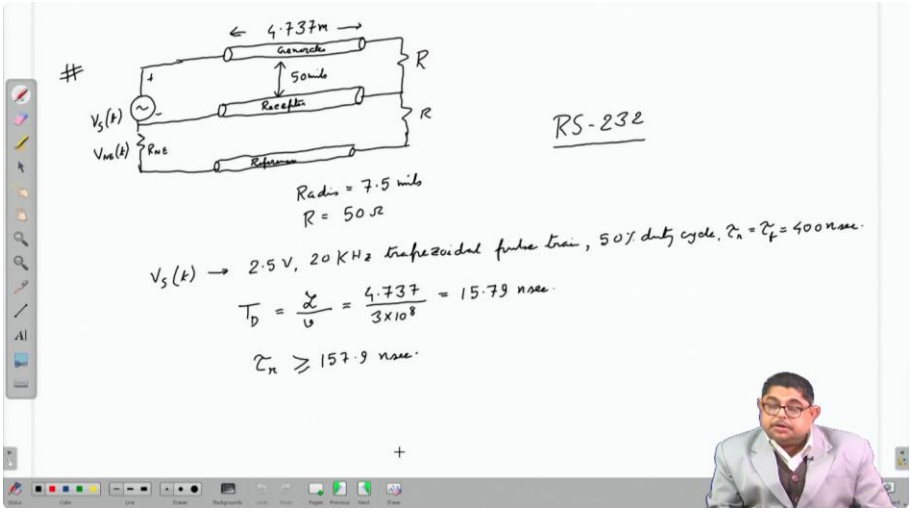
$$M_{NE}^{cI} = 9.21 \times 10^{-3} = -M_{FE}^{cI}$$

$$M_{NE}^{cI} V_s(t) = 9.21 \times 10^{-3} \times 2.5 \quad \text{at } t = \tau_n$$

$$= 23.01 \text{ mV}$$

$$= 0 \quad \text{at } t = 0$$





RS-232

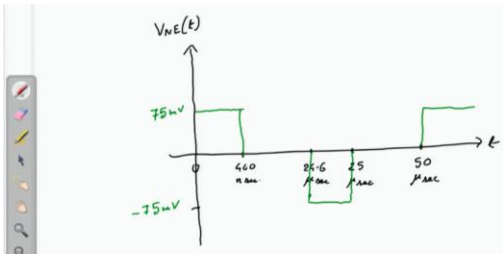
Radius = 7.5 mils

$R = 50\,\Omega$

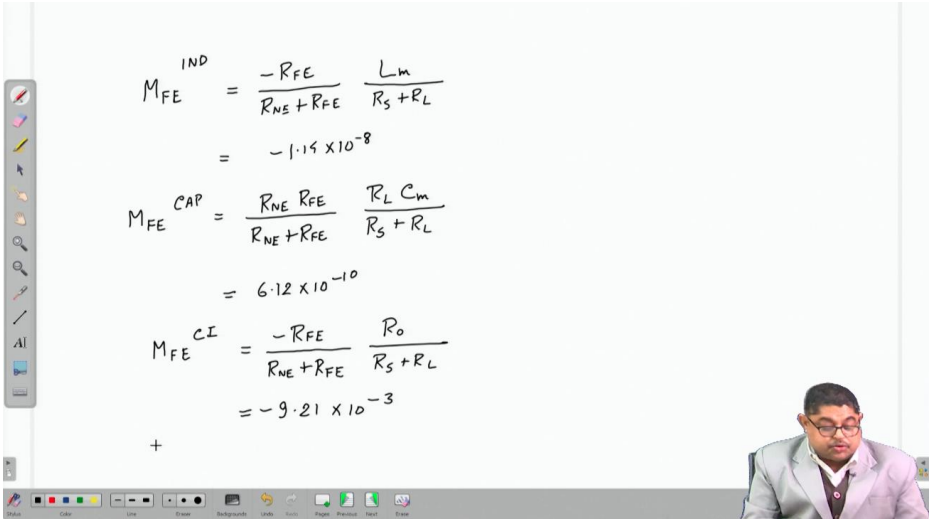
$V_s(t) \rightarrow$ 2.5 V, 20 KHz trapezoidal pulse train, 50% duty cycle. $\tau_n = \tau_F = 400$ nsec.

$$T_D = \frac{\alpha}{v} = \frac{4.737}{3 \times 10^8} = 15.79 \text{ nsec}$$

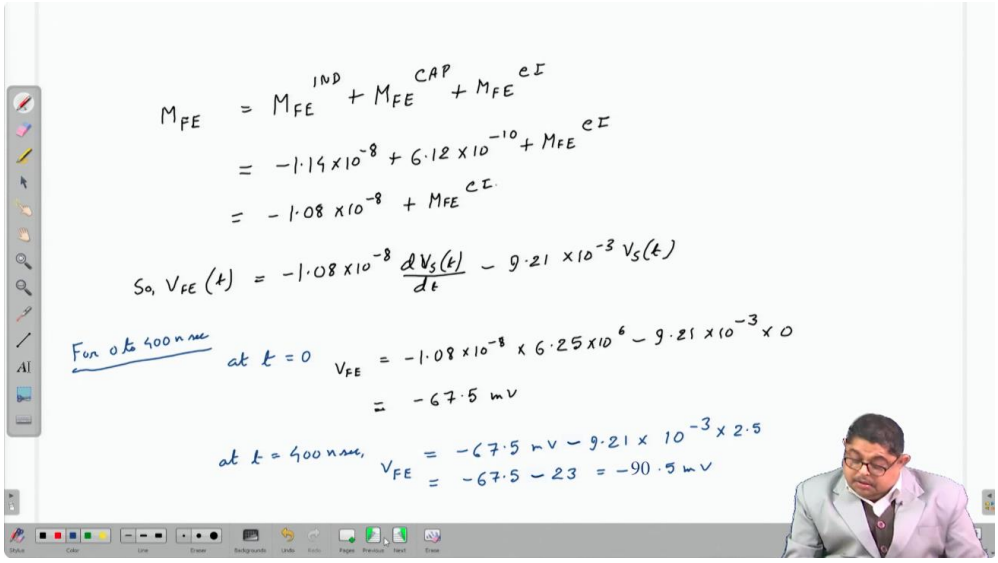
$$\tau_n \geq 157.9 \text{ nsec}$$



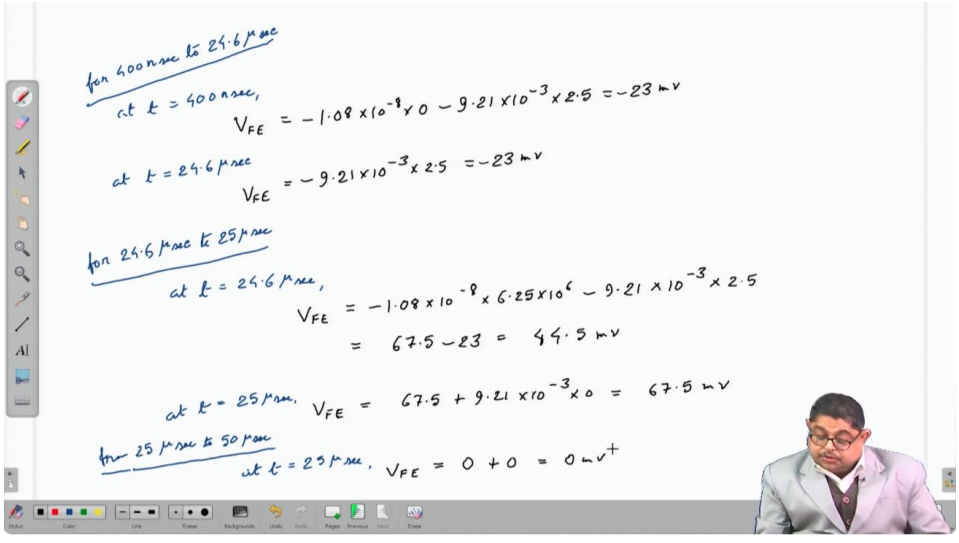
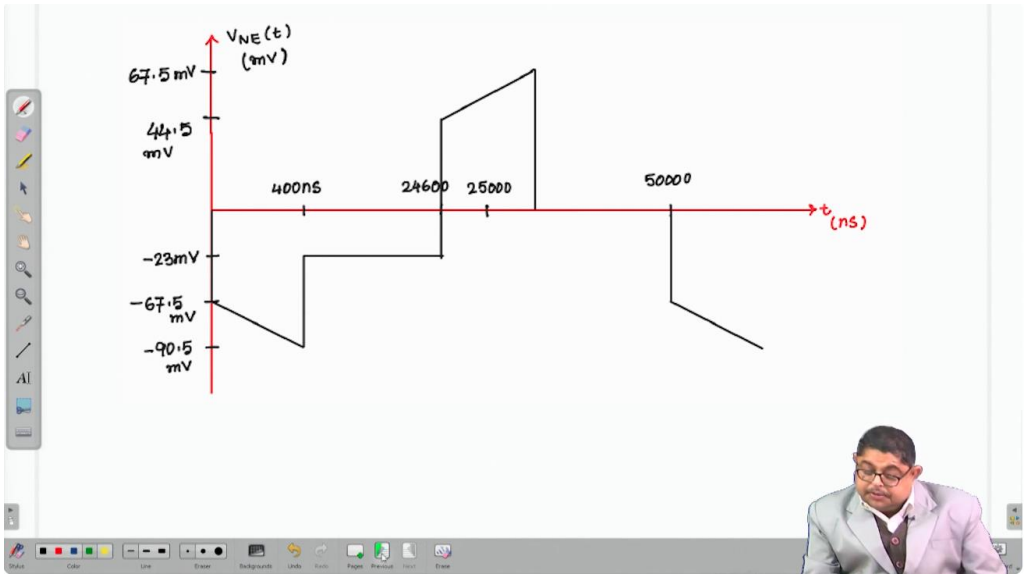
Now, what about the far end crosstalk? So, we know far end crosstalk is M f e i n d is minus R f e by R n e plus R f e L m by R s plus R L. So, if we put the value we know that is minus 1.14 into 10 to the power minus 8 M f e cap is R n e R f e by R n e plus R f e R L into C m by R s plus R L. So, that we have seen before that these value turns out to be 6.12 into 10 to the power minus 10.



So, what is the total M f e? M f e is M f e cap into R n e plus R L into C m by R s plus M f e i n d plus M f e cap plus M f e c i is equal to minus 1.14 into 10 to the power minus 8 plus 6.12 into 10 to the power minus 10 plus M f e c i. I am not writing this value because these two are frequency dependent term this is on be having frequency dependency. So, these two if I sum it will be almost this, but to be precise I am writing this as V 1.08 into 10 to the power minus 8 plus M f e c i. So, V f e t is equal to minus 1. into 10 to the power minus 8 d d V s d dt plus V f e c i is equal to 9.21. Now, I am putting its value V s t. Now, for 0 to 400 nanosecond at t is equal to 0 V f e is equal to minus 1.08 into 10 to the power minus 8 plus 9.21 into d V s dt is 6.25 into 10 to the power 6 9.21 into 10 to the power minus 3 into 0 because V s t is that time 0 it has a slope, but it does not have it. So, this is minus 67.5 millivolt. Similarly, at t is equal to 400 nanosecond V f e is equal to minus 67.5 millivolt 9.21 into 10 to the power minus 3 into 2.5 volt it has reached 2.5. So, that is minus 67.523 that is 0.5 millivolt.



Again for the falling part at all in the flat part for 400 nanosecond to 24.6 micro second this is the flat portion at t is equal to 400 nanosecond V f e is equal to minus 1.08 into 10 to the power minus 8 into 0 9.21 into 10 to the power minus 3 into 2.5 that is 23 millivolt at t is equal to 0.6 micro second V f e is equal to 9.21 into 10 to the power minus 3 into 2.5 is equal to 23 millivolt. For 24.6 micro second to 25 micro second at t is equal to 24.6 micro second V f e is equal to minus 1.08 into 10 to the power minus 8 into now again the slope has come 9.21 into 10 to the power minus 3 into 2.5 is equal to 67.5 23 is equal to 44.5 millivolt at t is equal to 25 micro second V f e is equal to 67.5 plus 9.21 into 10 to the power minus 3 into 0 is equal to 67.5 millivolt from 25 micro second to 50 micro second at t is equal to 25 micro second V f e is equal to 0.5 micro second V f e is equal to 0 plus 0 equal to 0 millivolt.



So, now we can draw the graph. So, this is the crosstalk waveform you see that it has significant variations with losses. The simple graph of this was just a 2 pulses coming in one cycle, but V f e graph is this with losses and V n e graph is this with losses. So, with this we conclude the discussion on crosstalk. So, that was one part of the radiated susceptibility. So, radiated emission we have seen, radiated susceptibility whole discussion, the far field radiated susceptibility, the near field radiated susceptibility or crosstalk. So, radiated susceptibility we discussed in detail and that we conclude today. So, how to find crosstalk is now you should be able to do in any practical case how to analyze crosstalk both in frequency domain and in time domain. Thank you.