Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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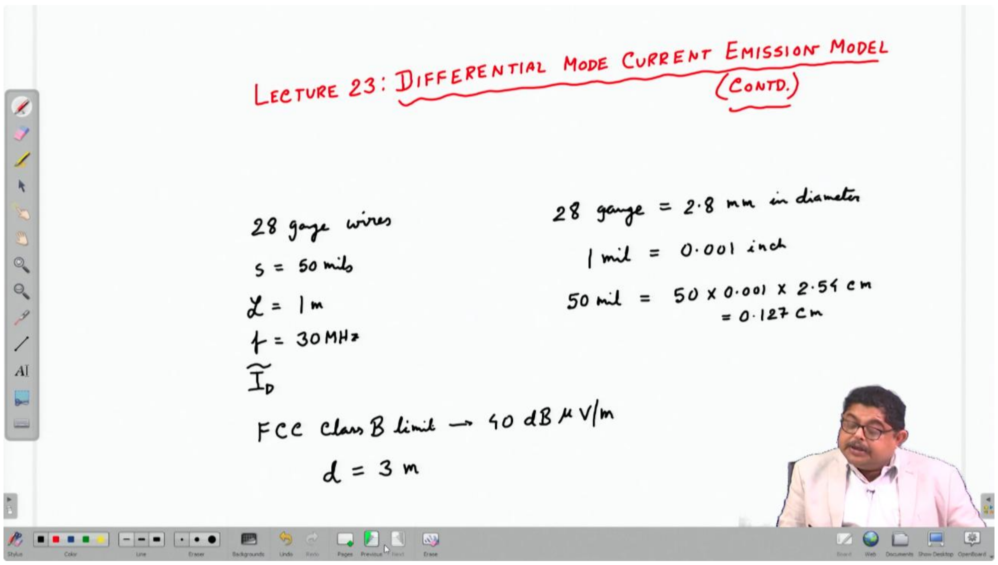
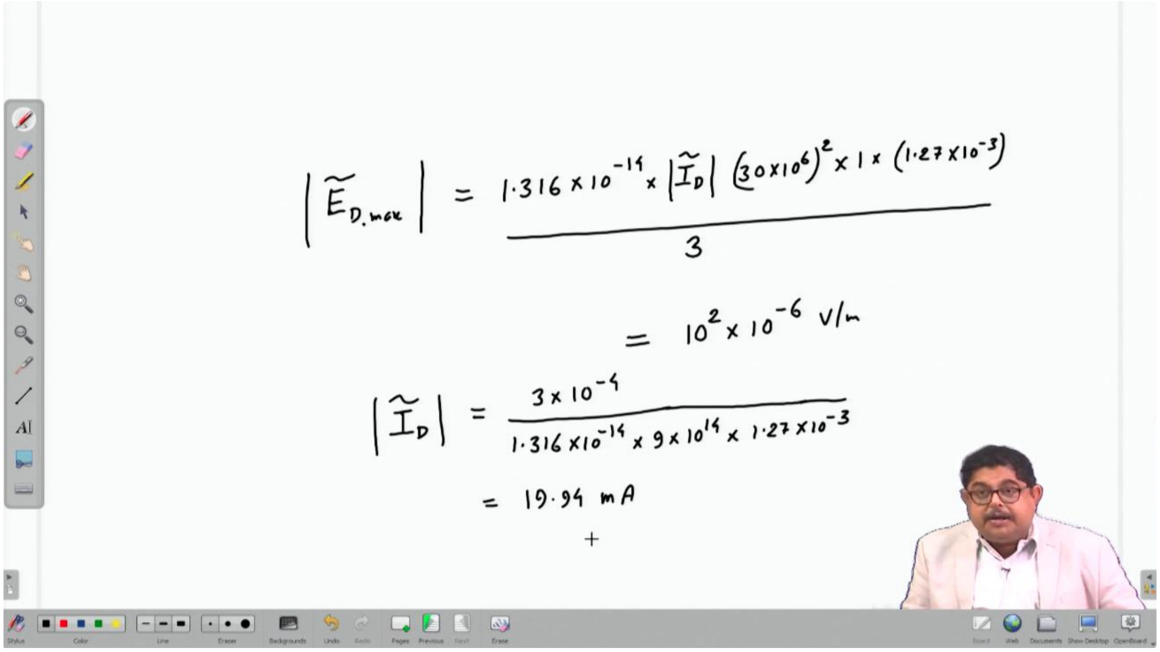
Week :05
Lecture 23: Differential mode current emission model (Continued)

Welcome to the 23rd lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Applications. We were continuing, we are continuing today the discussion that we were doing in the last class, the differential mode current emission model. We have seen the maximum electric field emitted by two parallel current elements. Now, so let us take an example to understand the model. So, let us consider the case of a rebound cable, actually you know that the cables that are come in bus etc or in PCB, the way you put the power supply or other data points those are in cables. So, there are considerable radiated emission from there. So, consider the case of a rebound cable constructed of 28 gauge wires, 28 gauge wires separated by a distance of 50 mils. The lengths of the wires is 1 meter and they are carrying a 30 megahertz differential mode current. The current value is not known. Find the current that will produce a radiated emission in the plane of the wires and broad side to the cable that just equals FCC class B limit, FCC class B limit. So, FCC class B limit for radiated emission is 40 dB at 30 megahertz. You have seen the limits etc. So, if you check that at 30 megahertz, it is 40 dB micro volt per meter. Now, FCC class so that means it is a FCC class B device maybe your computer some cable. So, and in FCC class B if you remember the measurement distance was 3 meter. So, that means we will have to take implicitly it has been said since it is FCC class B the measurement distance should be 3 meter. So, what is the maximum allowable current for you? This is the question. Now, here you see some industry terms are used, units are used, gauge, you here gauge. So, in various industries it has got different meaning in if you want to buy an Almirah steel Almirah you will have to specify gauge, 22 gauge is good, 18 gauge is very very good etc. So, also you will see that sometimes this British unit mill is used to specify some length. Now, let me tell that in EMC engineer should be familiar with this. So, what is gauge? Because ultimately this class is on MKs unit. So, what is 28 gauge or any gauge? Gauge is stands for actually it is the unit for diameter. So, if you measure any sheet its diameter any where it is or any cylinder its diameter that is given by gauge. So 28 gauge for electronics industry it is 2.8 millimeter in diameter. the wire diameter is 2.8 millimeter and 1 mil is 0.001 of an inch. So, inch you can easily convert to centimeter or meter and then you can come to your MKs unit. So, with this 28 gauge we got 2.8 millimeter and here it is given 50 mil. So, 50 mil means 50 into 0.001, 1 inch is 2.54 centimeter.

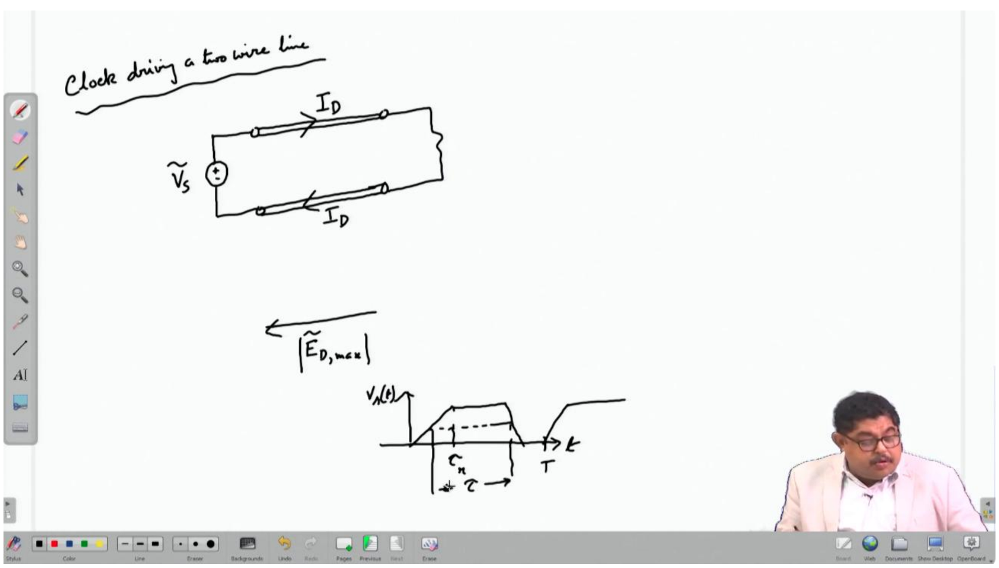
So, you got that this will be 0.127 centimeter. So, now you can put these all in your that equation.



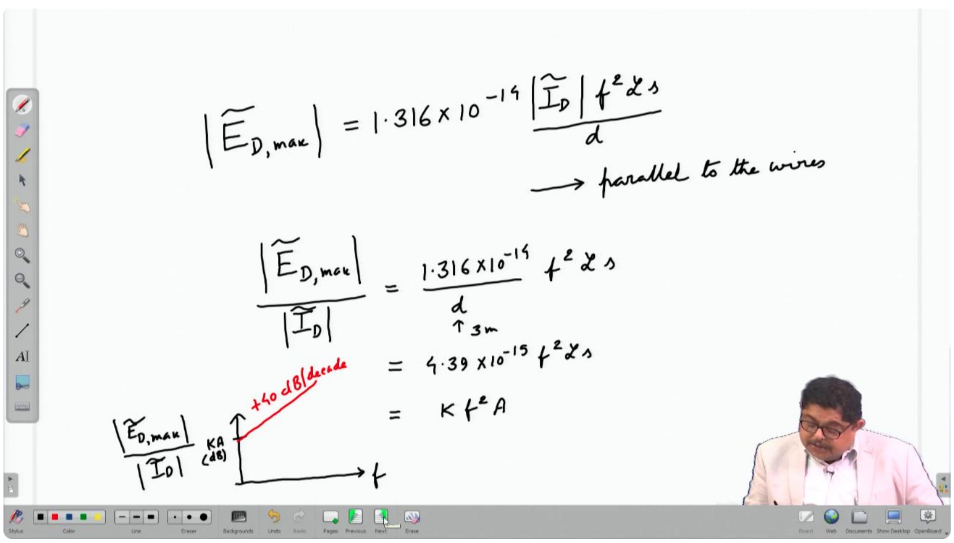
So, ED max will be 1.316 into 10 to the power minus 14 into ID. ID is the current at the center of the line into F square, F square is 30 into 10 to the power 6 whole square into line is of length cable is of length 1 meter and S is 50 mil. So, that is 1.27 into 10 to the power minus 3 meter and observation distance D is at 3. And what this will be the maximum thing, but it said that this should be just this field should be just equal to the value specified by FCC that is 40 dB micro volt per meter. So, what is 40 dB micro volt per meter in volts per meter how much it will be 40 dB. So, it is electric field a primary quantity. So, 20 things so, that will be 10 to the power 2 into 10 to the power 2 micro volt per meter. So, in volts per meter it will be 10 to the power minus 6 volts per meter. We can easily solve for ID, if you solve for ID you will get ID you will get 3 into 10 to the power minus 4 by 1.316 into 10 to the power minus 14 into 9 into 10 to the power 14 into 1.27 into 10 to the power minus 3. So, that will give you a 19.94 milli ampere. So, ID that means you can maximum have this much current roughly 20 milli ampere current is permissible to that ribbon cable. So, this is the thing that without doing anything just by that model you could estimate that what is the maximum value of current that I can use to satisfy the regulatory limit.

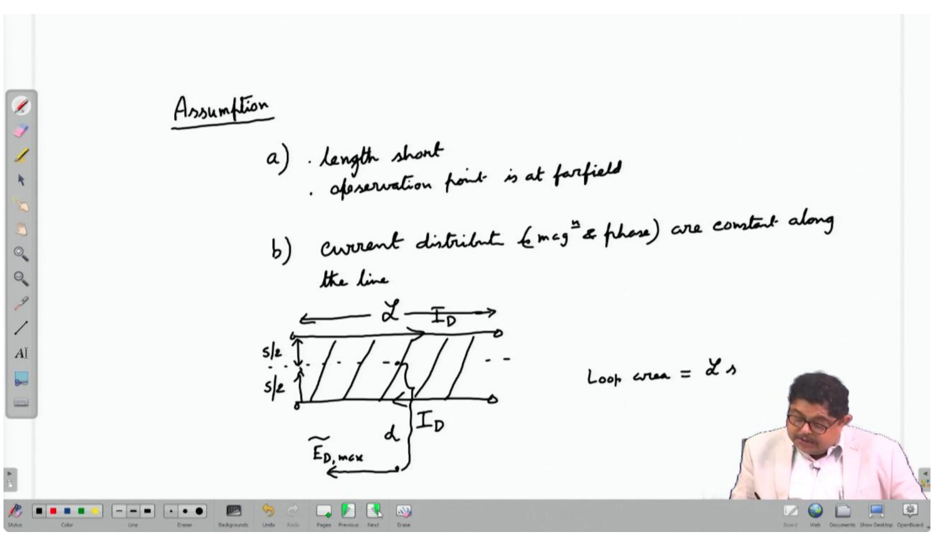


Now, let us see that in actual case the there will be a clock which will drive this line. So, if a clock drive the line that means I have a voltage source in the form of a clock let me call it Vs that is driving my this line. So, there will be ID here there will be ID here and I know that ED max will be in this direction and so, let us develop a model for this that with clock we have found for these, but many times without instead of knowing ID I may be knowing the amplitude of the clock. So, we have already seen what type of clock we are talking. So, let me write the heading clock driving a two-wire line this we are discussing now. So, what is the clock? We have seen we will talk of the trapezoidal sort of clock. So, our Vst will be something like this periodic clock. So, this is in time domain. So, important thing is this is our tau r, this is our T and also this is our tau.

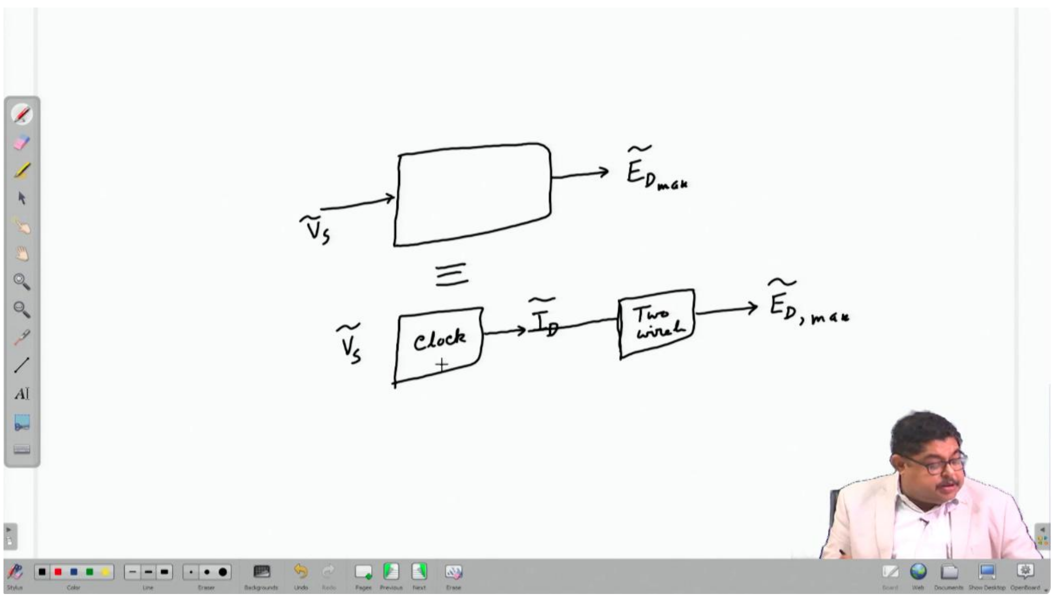


So, before going there let me see this thing that before this problem let us do one thing here I can say that the transfer function relating the maximum radiated electric field to the current is I can write easily from here that ED max by ID is equal to what 1.316 into 10 to the power minus 14 by D f square L into S. Now, for a measurement distance typically if we stick to FCC distance this will be 3 meter this is 3 meter. So, that value also we can put and that will come to be 4.39 into 10 to the power minus 15 into f square L by S. So, we can call that it is this is a value K. So, we can call K f square and L and S what is L and S? You see L and S. So, can I say that L is the loop area if I consider that the first conductor and second conductor. So, their area between encompass between them that we can call loop area. So, this loop area basically this one this loop area is nothing but L into S. So, K f square I can call that loop area A. So, this transfer function in frequency domain what will be its representation? So, I can say that this if I plot ED max by ID versus frequency. So, this will be in dB some value that will be K is logarithmic part into dB and f square means it will go with a line that line is plus 40 dB per decade. So, it is a line going with 40 dB per decade.

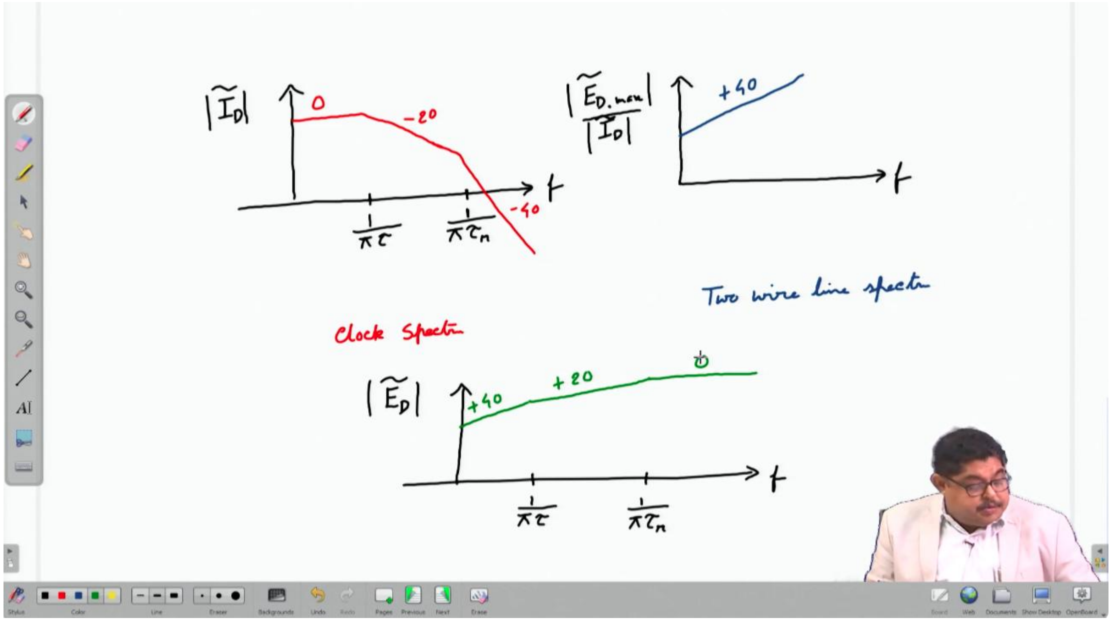




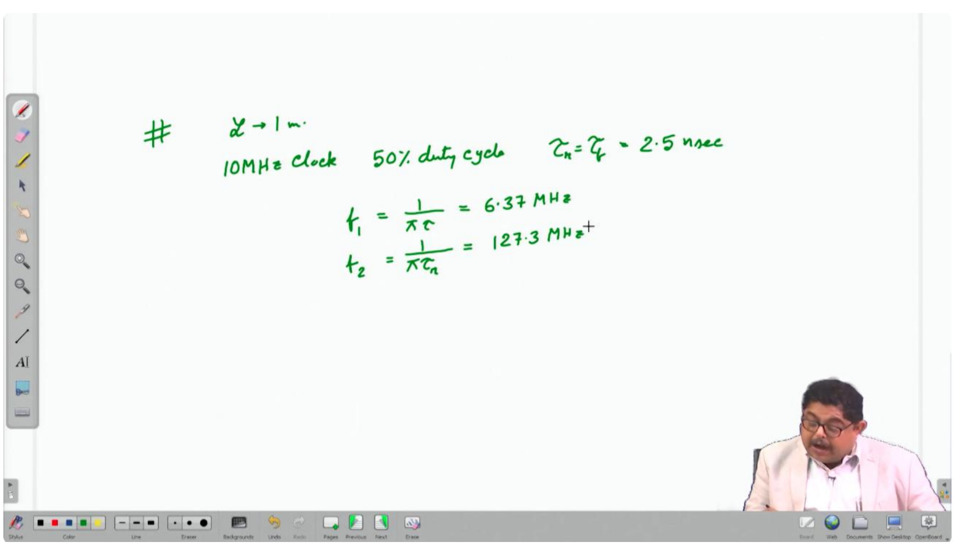
So what will be the if this clock drives it we know clock spectrum we know this transfer function. So, in the ED max we can consider as the output of the whole system and V S is the input of the whole system. So, I can consider that the whole system though radiating I am not considering that that I am giving as input V S and I am getting in the output ED. Now I am to find what is the ED max. So, that is nothing but can I say that this I can break into two parts that one part is V S it is giving its current ID and that ID is now driving a two-well line. And that is giving me ED actually it is giving ED but I am trying to find ED max that what is the maximum it can give. So, this is the clock I have broken this is equivalent to this. So, that means if I have this spectrum and if I know this ED max by ID transfer function. So, the whole system response is or system transfer function is multiplication of the these two. So, let us do that multiplication in frequency domain in logarithmic scale it is addition.



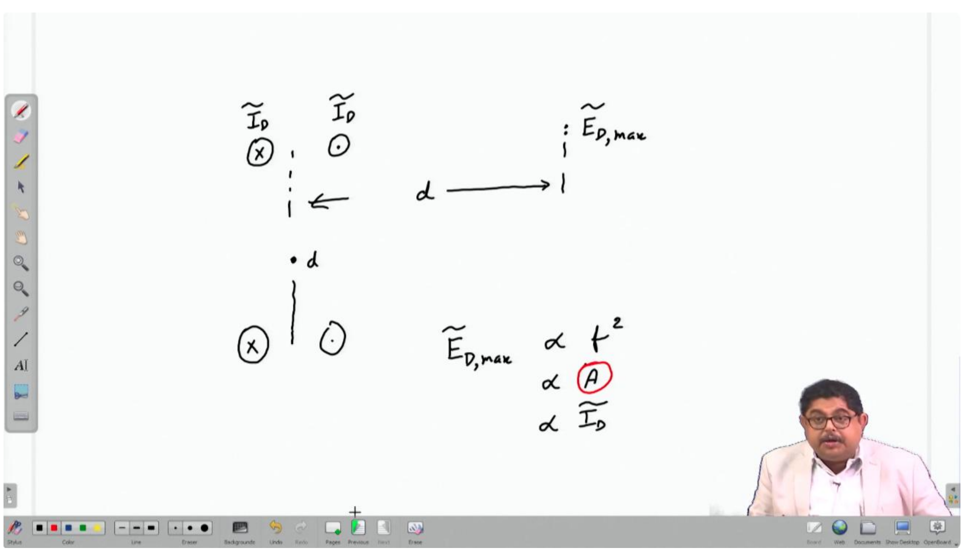
So, I know what is clock spectrum that means this will be ID this is f this is 1 by pi tau this is 1 by pi tau r and the spectrum I know is 0 20. So, 0 minus 20 minus 40 and the spectrum is ED max by ID versus f we have seen that that is goes with a plus 40. So, this let me write this is clock spectrum this is two-well line spectrum. So, I can now easily draw what is ED versus f that will there the break points will be two-well line spectrum does not have any break point 1 by pi tau r. So, it will be plus 40 then plus 20 then 0. So, ok.



Now, let us take an example that a two-well cable two-well cable length is 1 meter driven by a 10 megahertz clock train having 50 percent duty cycle and rise fall time of 10 megahertz is 2.5 nanosecond. So, find the maximum possible radiated emission. So, what will be the break points? Break points are what will be first break point f 1, f 1 will be 1 by pi tau is 6.37 megahertz, f 2 is 1 by pi tau r that is 127.3 megahertz. So, now you can calculate easily, but the point to note is the radiated emission problems due to differential mode currents tend to be confined to the upper region because you see upper frequencies are not sufficiently attenuated. So, upper harmonics they will create problem and if 1 by 2 pi 1 by pi tau r is away then it is getting amplified by 20 dB. So, 20 dB per decade. So, that is a problem that is why they create problems above 100 megahertz or so in practical cases. So, that is why the regulatory limits consider these things.



Also there is some more thing I want to discuss that about this differential mode. Suppose I have differential mode means this one is going inside the current is going inside and this one is coming out both are IDs. And obviously, the let us say that at this distance that means I am measuring and ED max will be parallel to the wires that means at this point let us say I am getting ED max. Now the maximum is in the plane of this white board broadside to them I am getting maximum, but suppose I now instead of these I want the measurement here still in the board, but I measure it at this point D. Now easily you can see that the now there are these two fields will cancel. So, at a point or at every point equidistance from where and perpendicular to the plane of the wires this point is perpendicular to the plane of the wire. So, ED cancels so that means if I rotate the parallel to parallel wires then the values will change that means they are very sensitive to rotation, rotation of the cable. So, differential mode currents while doing measurement you should be aware that by rotation of the cable it changes a lot also from the formula of radiated emission from differential mode currents we can say that ED max varies with F square varies with loop area A and varies with current level ID. So, that means what you can do that you see frequency you cannot change generally because frequency is chosen from other angles clock frequency, but you can reduce A or you can reduce the current ID, but ID is a functional current it has some functional purpose. So, whether you are permitted to do that that is not so easy, but loop area reduction of loop area is possible also ID to reduce ID what you can do instead of directly reducing the ID value you can increase the pulse rise or fall time or by reducing the pulse strain frequency you can achieve that because these will move the two break points lower in frequency possibly causing the spectrum to roll off at a faster rate at your measurement frequency. Now, this one reduction of loop area is a very good alternative actually for EMC design it is much preferred.



Suppose I have a PCB and generally there you have a clock that clock is driving some let us say some AC board etcetera. So, current is going here current is coming back. Now, you see that this is your loop area now maybe the PCB designer has placed these you can always check that whether this loop area can be reduced because that will reduce your emission many times you will see that PCB designers to put this AC board away from the clock so that their distance increases and they get various path options because there are other components etcetera so path options increases for them, but as an EMC engineer you will try to move this AC etcetera as near as possible. Similarly in case of wires suppose you are having a rebound now many times this is done the C this is an aesthetic design that C then its return path is C dash B its return path is B dash A its return path is A dash, but what loop area you created let us take A dash and A. So, this is your loop area like that in other cases, but you can have an alternative that. So, in this case this is your loop area now this one may look aesthetic, but from EMC point of view this will be definitely preferred that actually if you calculate you can see that probably you can make a 3 dB reduction by doing this thing instead of doing this thing instead of this thing. So, this is where your knowledge of EMC design comes into picture. So, differential model we have discussed in the next class we will develop the common mode emission model. Thank you.