Lecture 11-

Usage of Lattice Diagram

Hello and welcome, to NPTE MOOC, electromagnetic waves in guided and wireless medium. This is module 11, where we will look at some additional examples, of usage of lattice diagram. Okay?
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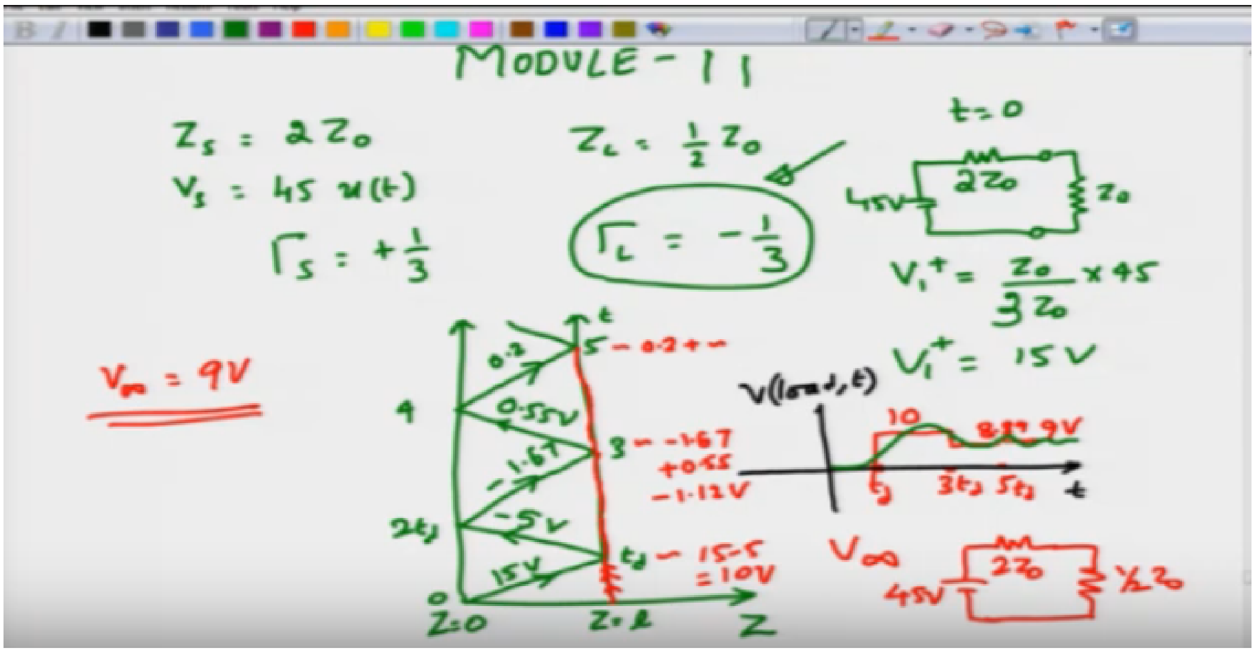

So, let us consider a circuit, wherein we have a same situation as in module 10, you have said s, you have V s, which will be connected to the transmission line at T, equal to zero why a switch. So, I can represent that action by writing this V s as, 45 U of T value, of T corresponds to the step voltage. Okay? This time, what we are going to do? Is to make the source impedance larger than the characteristic impedance of the transmission line, the load impedance ZL, is now less than, the characteristic impedance of the line. Okay? This situation also occurs, in digital interconnection ,where source is actually switching or the source IC is switching from, a low to high whereas ,the logic gate at the load will be no presenting usually it will be in the lower state. So, it will be presenting a very low impedance. Okay? So, these situations are you know? Well approximating the actual, system in I mean actual application where one logic gate will be driving the other logic gate and therefore studying this scenario is also important to understand how, the pulse may be, distorted or how the pulse or how the voltage is actually changed on the transmission line. The first step to solve this transmission line, problem is as, the same as the last time but this time gamma L, will be minus 1 by 3 and gamma s will be equal to plus 1 by 3, clearly because, Z s, is now larger than, Z naught and that

L is now large smaller than said not .Okay? To calculate V 1 plus, V still use the circuit at t equal to zero the equivalent circuit. So, there is a transmission line, with the characteristic impedance Z naught this is two times Z naught, connected to 45 volt source. So, clearly the voltage that you are going to launch on the transmission line the input terminals of the transmission line, at T equal to zero, will be v1 plus, given by Z naught divided by three Z naught ,times 45, which I think, is about fifteen volts, so please correct, again if I am wrong. But, if not let us move on to the transmission sorry, the lattice diagram. So, this is the z axis as before this is the time axis and now ,you have to launch, gamma sorry, you have to launch the voltage v1 plus which is about 15 volt, on to the, transmission line. So, at t equal to 0 so, this is that equal to 0 plane, this is Z equal to L corresponding to the load, at time T equal to 0 ,we launched the voltage, which is 15 volt on the transmission line, at which point it gets reflected ,but this time the reflected voltage will be negative voltage, why because gamma L, sine of gamma L is ,negative or less than zero. Right? So, gamma L is minus 1 by 3 so, 15 times minus 1 by 3, will be minus 5 volt, which would be reflected back and when you have when this voltage reaches the source, it will again be reflected, towards the load, but the reflected voltage amplitude will be minus 5 by 3, minus 5 into 1 by 3. So, that is minus 5 by 3, which is roughly minus 1 point 6 7 volts, this gets further reflected back ,to become point 5, 5 volt please note that, the sign has now changed, because the load has the reflection coefficient which is minus and a minus signed incident wave is, you know? Incident on the load. So, their product will essentially become positive, so the voltage that gets reflected off, will be 0.55, which is positive voltage, this divided by 3 which is roughly 0.2 volt or point to one volt maybe or point two three volt, whatever that is? That would be reflected back and that would again be reflected and so, on and so forth. Okay? So, these epochs, where you are actually seeing these reflections are 0 ,this is TD, this is 2 TD ,3, 4, 5 TD and so on, so, we have stopped at, this point and as before our interest is to plot the voltages at lode as well as at the, input terminals of the transmission line. So, first plotting the voltage, at the load, as a function of time, we see that ,at T equal to zero there's nothing's going to happen and some change ,will be seen only at T equal to TD ,what would be the voltage that you are going to see here? That would be 15 minus 5 which is about 10 volt. So, at t equal to TD, the voltage at the load will jump, to a value of 10 volt, this will happen at T equal, to TD. So, those who, you know? Are having troubles I hope this is understood, what we have done is, we have moved along the time axis on the load plane and since there is no line intersecting this time axis, there is no voltage until t equal to TD has elapsed. Okay? At T equal to TD, you have an incident wave and a reflected wave, therefore the total voltage that would be appearing across the load, will be incident plus reflected which is equal to 10 volt here, I hope this, poor part of this one is very clear ok. Now, you continue your journey TD, onwards nothing is changing, until you hit 3 TD, where there will be a partial voltage, of minus one point six seven plus, about 0.55 volt which is roughly minus one point, 1 2 volt. Right? So, there will be a step, change from 10 to about nine eight point eight, eight something or eight point nine something ,which would happen at 3 TD, the step itself, is a value of minus one point one two. So, I will write this as roughly, eight point, eight nine and then if you continue your journey, you will see that there will be a point two volt, incoming or incident, plus point two divided by three, minus of point two divided by three, is very small so, I can neglect that, that will also be present. So, there is going to be a small increase, in the voltage at 5 TD ok. Let us, calculate what would be the asymptotic value. So, this is roughly nine volt. Okay? Eight point nine plus, about point one volts or 0.18 volt something like that that would be about nine volt. Okay? V infinity for this circuit is again very simple, you have to Z naught connected here and half a Z naught off voltage coming from sorry, half Z naught of impedance coming from the load, connected to 45 volt, as the source. So, you apply voltage divider and we infinity will be equal to, nine volt you can check this. Okay? So, what we have seen is that? Again there is some sort of a ringing effect. Okay? There is a, ringing effect, in the sense that you know? The voltage oscillates and then eventually joins or you know? Asymptotically or just the steady state value of nine volt. So, that ringing effect is still there, because one of gamma has become negative in sign. Right? So, this gamma L, being negative means that the voltages are going to be up and down, not just adding and subtracting. So, this under damped, nature still exists even in this particular scenario. Okay? This is interesting. Right? So, when you have the source, impedance being larger than the characteristic impedance or when the load impedance being carried larger than the characteristic impedance, in both situations, you did see that there is an under damping or ringing effect. Okay? So, if you want to avoid this ringing effect, what you have to do?

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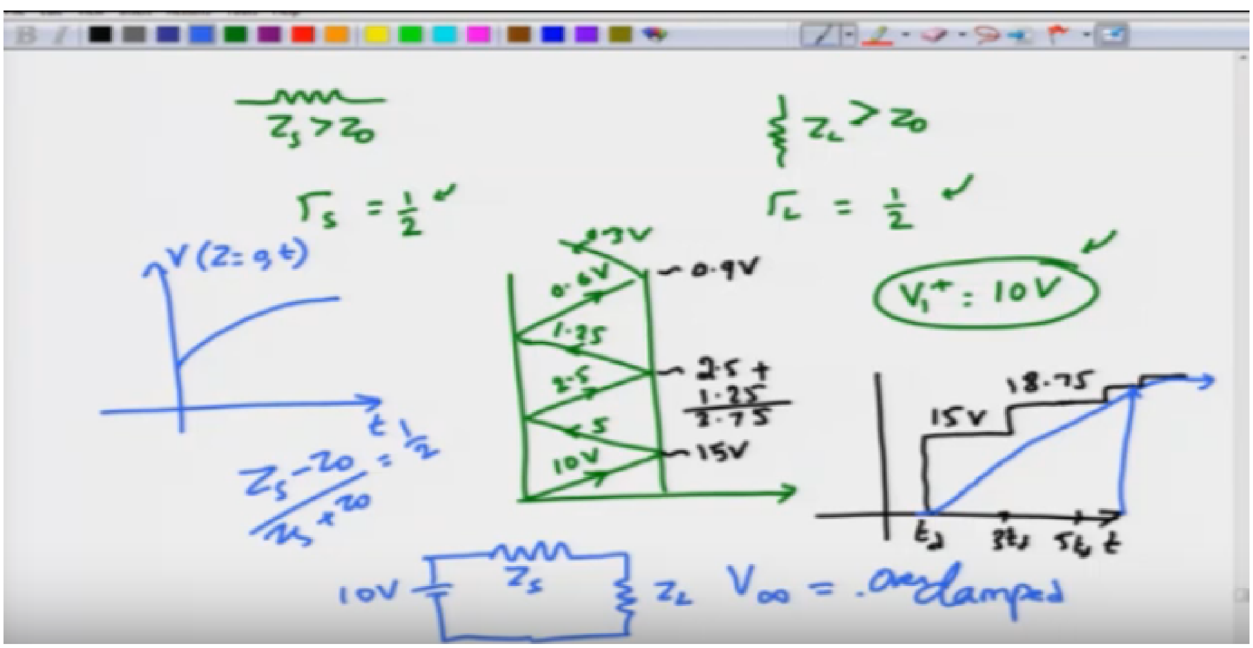

Is to ensure that the total load impedance or and the source impedance, both will be greater than Z naught. So, both source as well as, load has to be greater than Z naught, only then both gamma L, as well as, gamma s, will be larger than the, than each other. Right? So, because the voltage is, going overshoot and undershoot may not be desirable all the time. So, if the voltage overshoot is very large, then what it means is that across, the transmission line term not the load and momentarily at least, the voltage is actually very large. Okay? A large voltage across a transmission line is actually a bad thing, because there is a dielectric in between that and that dielectric is not a perfect dielectric, you know? That dielectric has a certain breakdown voltage. So, if the overshoot happens to be much larger, you know? Very, very large in some unfortunate scenario, then that large voltage may actually burn out the dielectric and cause sparks, between the transmissions lines itself. So, this is known to happen in, systems where the voltages themselves are very high, you know? If this power transmission cables, are dealing with voltages which are in the order of 220 volts and so on. So, any overshoots, a drastic overshoot, will always been a bad news for them. Okay? In the problems where we are considering the digital logic applications, this is not such a big issue, although it does, lead to some problems of its own. But, at very large voltages, any drastic overshoots, actually is a pretty bad news for the entire circuit. Okay? Now, coming back to this problem, if you want to avoid that, overshoot you want to under sorry, over damped the system. So, over damping the system, is possible, by taking that L to be greater than Z naught and Z s to be greater than Z naught, for you know? Simplicity case, let me take gamma L, to be equal to half and gamma s to be equal to half. Okay? So, this is all Right. Now because gamma L, is equal to half, with a positive sign, indicates that ZL is greater than Z naught. Okay? And gamma s being equal to half, also indicates that this is, the same scenario, it is actually greater than Z naught. Okay? In that case, what would happen to our lattice diagram? So, let us assume that V 1 plus, happens to be 10 volt. Okay? I'm not you know? Calculating the exact values by looking at the circuit I am, just basically picking up some convenient number,, I have adjusted the resistance values, the characteristic impedance and the load impedance, such that I want gamma L of ½, gamma s of 1/2 and a launch voltage, initial launch volt on the line to be, about 10 volt. Okay? So, we you know? Send in ten volt and then a five volt will be reflected back, next time there would be 2.5 volt, incident onto the load, which would then be reflected back on to 1.25 volt. Right? And then it would again, go back roughly about 0.7 volts or 0.6 volts approximately 0.6, 0.6 3 volts and so on, it continues this way this is point the Volt and so on. Okay? So, now if you draw the voltage, at the load. Right? So, if you draw the voltage at the load you will see that, at time T equal to TD, the voltage will jump, to a value of 15 volt. Right? This is the point where you are going to jump to 15 volt, then the next partial change in the voltage, would be of a, value to 0.5 plus

1.25 which is about, 3.75. So, from 15, it will jump to, 18 point seven five, this is happening at TD, this will happen at 3 TD and then again there will be one more jump .Okay? At 5 TD, there will be another jump, but this time the, jump is not so high that, is about point nine volt rougfly,so that would make it about 19, point something. Okay? So, that will still be a jump and so, on. Right? So, this is, as you can clearly see this is an under damped scenario, why because the voltage kind of you know? Is increasing and reaches the asymptote, asymptotically it reaches the steady state value of V infinity and I believe, draw drawing the voltages, at the load sorry, at the source, as an exercise to you, meaning you need to figure out what would be V at z equal to 0 for all times. So, at least for a, time T equal to 5 TD or 4 TD and you will again see that, there will be a, you know? Dumps some kind of an over damped behavior, the voltage will start. So, in this case it won't start at zero, obviously sorry, this will actually start at, some known value and eventually converges on to the, final or asymptotic value V infinity, what is V infinity in this case? Well you go back and calculate what is Z s, you can do that because there des is gamma L is given by, Z s minus, Z naught by, Z s plus Z naught and this should be equal to, half and you can calculate what would be Z s in this case? The same value will be for Z L as well, because you know? Gamma L is, the same as gamma s and then apply a 10 volt, here and then determine what would be the voltage V infinity, I believe this also as an exercise for you, it should be around 19 20 volts range, but I will leave this as an exercise for you to, figure out what would be that voltage. Okay? So, we have seen that, this case, corresponds to an over damped scenario, the advantage of this over damped scenario is that, there are no overshoots, unfortunately you still have to wait about 40 D or something, for the voltage to actually change from, say zero volts at the load, to the know, about nine I mean, one percent of the final value or ten percent of the final value, whatever that value that you decide. Right? So, it is still going to slow down your systems, but at least it has gotten rid, of the problem of overshoots.

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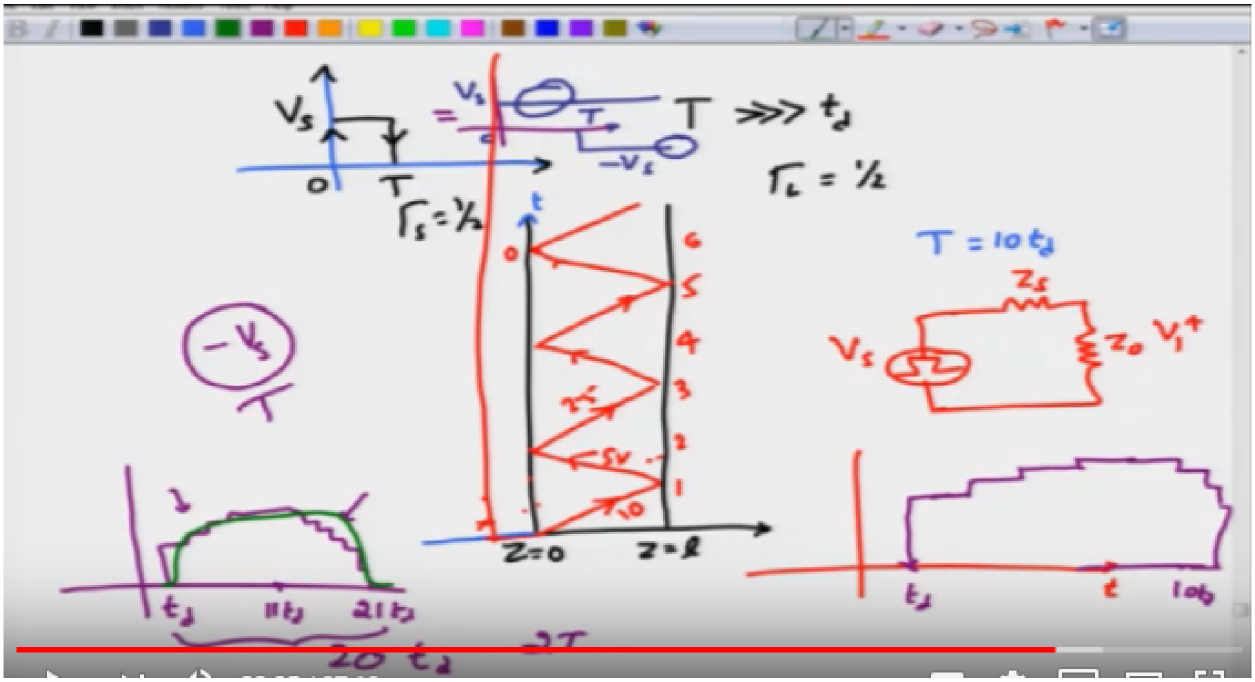

So, we have so, far seen Trans you know? This lattice diagram, being used with a constant voltage source or a DC voltage source as we, would call it. But, now I want to apply a pulse and then, figure out what would happen? When a pulse of a certain duration T, would be launched onto the transmission line, clearly you may, actually you know? Without doing any calculations, tell me that, when T is much, much, much larger than the propagation delay time, then there is no problem with this one. So, if you launch whatever the value say V is, that V s will be available, you know? For very long times of TD. So, then this voltage will actually, not really you know? Be, distorted much but, on the other hand, it will be distorted, quite heavily. So, let us actually verify that, but I mean maybe I am wrong here, but let's just verify, whether having T, that is duration being much larger than TD is good or duration being much smaller than TD is good. Okay? The way to, modify this, lattice diagram is to again I am, going to assume gamma L is equal to half and gamma s is equal to half, just for simplicity there is nothing else, you can you know? Consider different cases. So, the way to adapt this, lattice diagram, is to, actually draw two sets of lines. Okay? One line corresponds to the rising edge and the other line corresponds to the falling edge of the pulse of course, we have assumed the pulse to be having, zero rising time and zero falling time but, in practice you would actually find pulses, more in this nature. So, there will be a finite rise time, all time. Okay? However this case is slightly more complicated, not very much but, slightly more complicated and this is better left for a different course. So, I am not, going to look at, this one, I am going to assume, that the rise time of my pulse, was equal to 0 and therefore I am, all Right? Looking at only the lattice diagram for rising edge and the falling edge. You can, by superposition, think of this pulse voltage, as two volts I mean, two voltages. One is a voltage which is turned on V s and then there is a voltage which is minus V s. Right? So, that for all times, but this minus V s voltage source, is applied at, T equal to T and then you have this, voltage applied. Right? At T equal to zero and the response of your, transmission line because it is linear, can be broken down into the response to V s, source as well as to, minus V s source. In fact that is, what we mean by writing rising edge and the falling edge. Okay? So, we start with the rising edge, for now we will assume that T is, about say 10 time's TD. Okay? So, what does this mean? This is my time axis, this is on the source that I have. So, T equal to 10, TD means that, the voltage that I have, will be of this particular form. So, I am assuming that this is 10 TD, we may have to calibrate all the numbers here, but this is the, time when pulse will end so this is T equal to ten, you can assume T D equal to 1. So, that numbers can be easily written off and the rising edge of this pulse, which is that, this edge, will begin to propagate on to the transmission line, as soon as the, switch is closed that is as soon as the, pulse is launched it will begin to propagate of course, it won't be exactly equal to Vs. Please remember, the voltage will still be v1 plus, which is calculated by the equivalent circuit, that you are going to write, however this is a voltage source sorry, this a pulse source, with the value of V s and then this is, Z naught and then this is, equal to Z s, we have chosen Zs and Z naught to be, of the form Z is equal mean gamma is equal to ½. So, by that you can actually find out, what would be Z s ok. And in terms of Z naught, at least you can find this out and then find out v1 plus, it will always be less than this, v1 I mean, V s that you are actually applying ok. So, v1 plus, will be less than, v1 than V s but, it would be the one that would be launched ok. So, we are going to launch v1 plus, this edge will be launched and you can clearly see that, after certain time you know? After just a small amount of time, this portion of the voltage would also be launched. So, technically you could, account for that by writing another dashed line, you could account for this part of the pulse parroting another dashed line or no straight line that would go from 0. But, these points which we will call as say, 'A, B' and so on are also displaced in time. Right? So, this is occurring slightly after T equal to 0 a point and then B is occurring out at a time T which is greater than time corresponding to a and so on ok. However to, not clutter the lattice diagram and also to, you know? Keep the matter simple, we won't show, what is happening to the instance of the pulse? At B, A, B and so on ok. Because that is not really important, we know that this will all be, in eventually be, launched onto the transmission line. Right? So, this line would go, now the pulse from the source has not ended. Right? However there will be a reflected voltage ok. So, we will assume this voltage to be whatever v1 plus, so let's say we'll take this to be ten volt. So, the voltage that would be reflected back, will be 10 by 2 which is 5 volt, the pulse has not yet ended. So, there is still 5 volt, this all corresponding to the leading edge only ok. Please remember that, so this will be 2 point 5, this is TD, which is 1, this is 2, this is 3, then this is 4, this is 5, this is 6 in fact this we should not even end here, I have to continue my pulse, far away onto the page as well, I just marked 3, 4, 5 and this one was 6 so, so we have not even exhausted up to 10 ok. So, the pulse continues to, exist, the pulse of minus Vs will go to 0, only at the at

T equal to 10 TD, but so far the leading edge is actually taken, the multiple reflections. Right? So, now when you start looking at, what would be the voltage that you are going to get, you will see that, as a t equal to TD of course, the voltage actually starts to, you know? Change and this would actually be, 15 volt. Right? So, this would be 15 volt corresponding to the rising edge and from 15 it would again increase slightly and then increase slightly and then increase slightly,this is what you are going to get. Now, you can imagine, although I have run out of the page here, you can imagine that, when I send in minus Vs voltage source, which is turned on at, t equal to t, which is a 10 TD. Right? So, if I extend this one to 10 TD, what would happen is? That voltage would be negative. Right? Because it is, minus 10 and both gamma L, as well as, gamma s are positive and eventually go down and becomes zero, at 20 TD. Okay? So, the pulse that you are going to see, will actually be looking something like this so, so this is what you are going to get I mean, I have drawn too many steps here, but this are not the steps that you are going to get, you have to do a slightly better job than me, in writing the actual number. So, I have run out of the page, but you take a longer page. So, that you can write all this. Okay? But, what you notice here is that this started off with T, well 2td and then the voltage changes to ten TD no, which shows up on the load at 11 TD, somewhere and then continues up to some 21 TD. Right? So, that you have a total of about, 20 TD which is basically two times propagation length, for the pulse to actually go back and go to zero again, because after this there won't be any pulse. Right? So, you have seen that, the voltage roughly can be written in this manner. Right? It is going to be a pulse but, the pulse is you know? Having the same duration but, then not much of a distortion as seems to have happened here, you know? If I was the one, who was at sitting at the load, I would see these jagged edges, which is true I'm going to see those jagged edges. But, overall the pulse is kind of showing the same shape, as the, pulse that has been launched. When the case was, the pulse duration to be very, very long, compared to the propagation delay itself.

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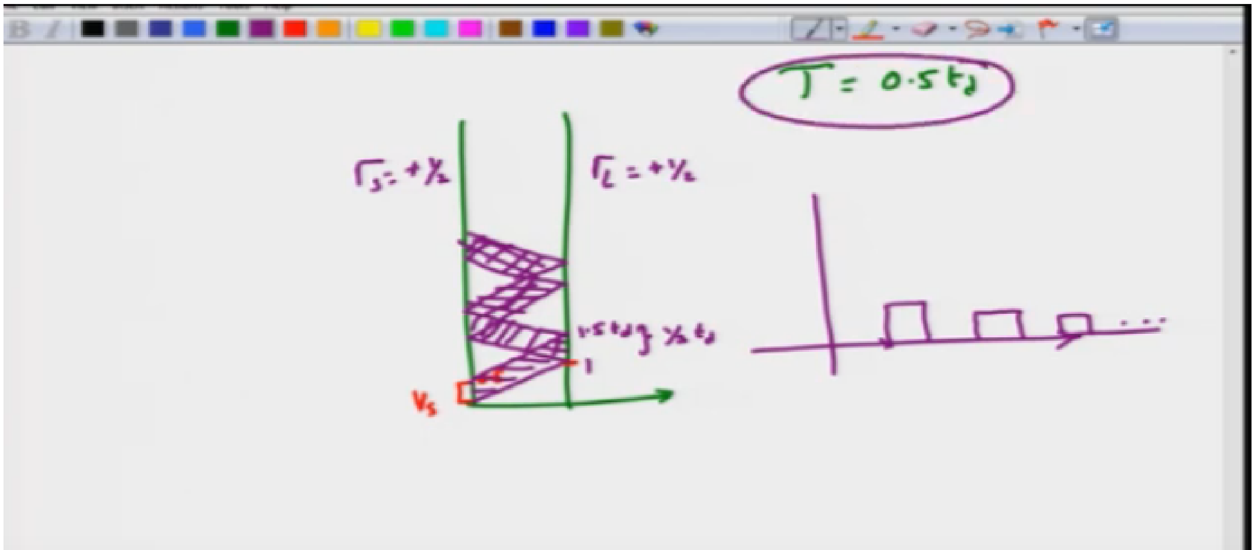

Now, if you switch the scenario and then say T's say just about 0.5 times TD, now it is like, you know? The duration itself, is just half the propagation delay, then you can clearly see that, if this is my, you know? This is my, lattice diagram and if I call this as TD, then the pulse itself will, be ended here. So, this is pulse of amplitude Vs, of course on the line it would be v1 plus, but this will end at, 0.5 TD it sells. Right? So, the leading edge, as it propagates, it would take one time TD to reach, whereas this 0.5 would reach at, three point, naught three point. What is that? 1.5 TD. So, this will reach at, one TD this will be now reaching at 1.5 TD. But as soon as the leading edge has reached here, the voltage will actually be reflected and similarly this voltage would also be reflected, all the time the duration here is just about half TD, which is exactly equal to the pulse. So, there won't be any voltages around this I mean, outside of this shaded region, the pulse will always be within the shaded region this line will be reflected ,this will be reflected, the pulse will be reflected. So, what you are actually seeing is that? The pulses are being reflected. Okay? So, the receiver, will actually see a sequence of pulse, beginning at t equal to TD it will see a, pulse which looks like this, which has a duration of about half a TD, then again at 3 TD it will see. But, this time the pulse amplitude would be smaller and again it would be smaller and so on and, so forth ok. I'm, assuming again gamma L to be plus 1/2 and gamma s to be equal to plus ½. So, in both cases, the voltages will only add but. Right? No there is nothing to add, ok. So, everything is done, in the sense that, this voltage was b1 plus, then it could be v2 minus, which is smaller than V 1 plus, V 3 plus will be smaller and so on and, so forth all the partial pulses that you are seeing will be smaller. So, what you actually have, in this scenario, is that, instead of a single pulse, you now? Have a sequence of pulses, Okay? Perhaps their amplitudes are decreasing, because the way gamma L and gamma s are present. But you launch a single pulse, you now get, multiple pulses and there is nothing you can actually do about it, unless, you a match the load or at least match the source ok. If you match the source, then you will get a pulse and then the reflected pulse will come back, but it would be completely absorbed by the source or if you match the load with the characteristic impedance of the transmission line, then the launched pulse would come, it would be absorbed by the load and therefore no voltages will be reflected back. So, these are actually serious problems, you know? Like in typical digital logic gates or digital PCBs that you are going to have, you know? Digital ICS designs, then this kind of a behavior, limitation because of the transmission line, is an important phenomena and as I have told you, there are multiple, ways people have been you know? Working on to reduce these kind of distortions, which would actually be a nice course on signal integrity. You may look for it in, in the online or Internet. Thank you very much.

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