Electromagnetic compatibility
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Module 5.2
Solution to EMC Problems

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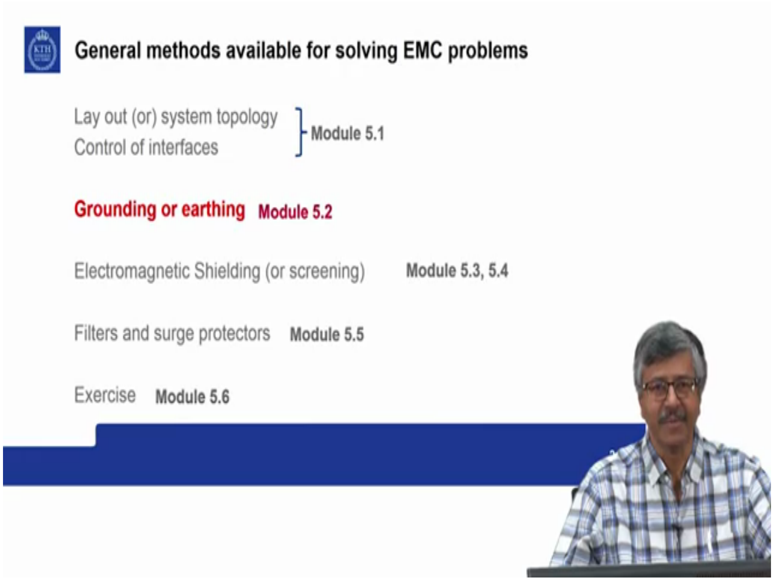

Solution to EMC Problems now we can look at module 5.2 that is second module in chapter 5. So in this module we will go through some of the principles involved in grounding or earthing.

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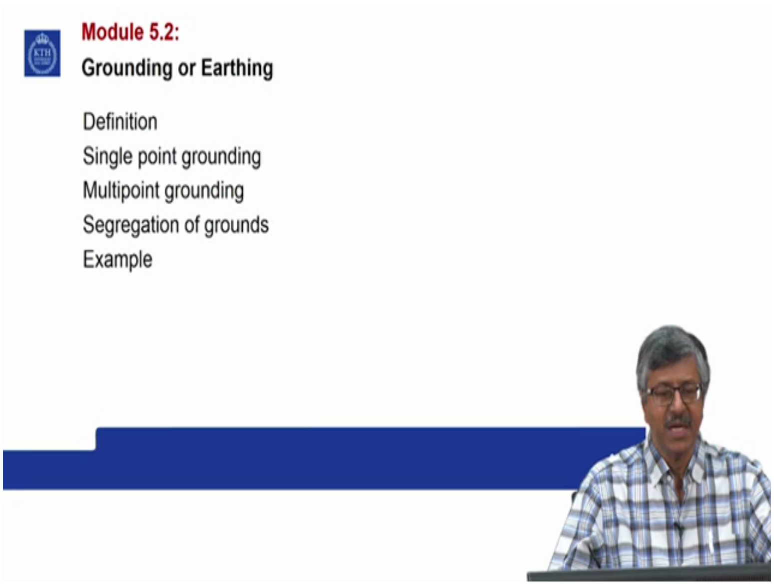

The single point grounding concept, multi point grounding, segregation of the grounds and some examples will be treated over here.

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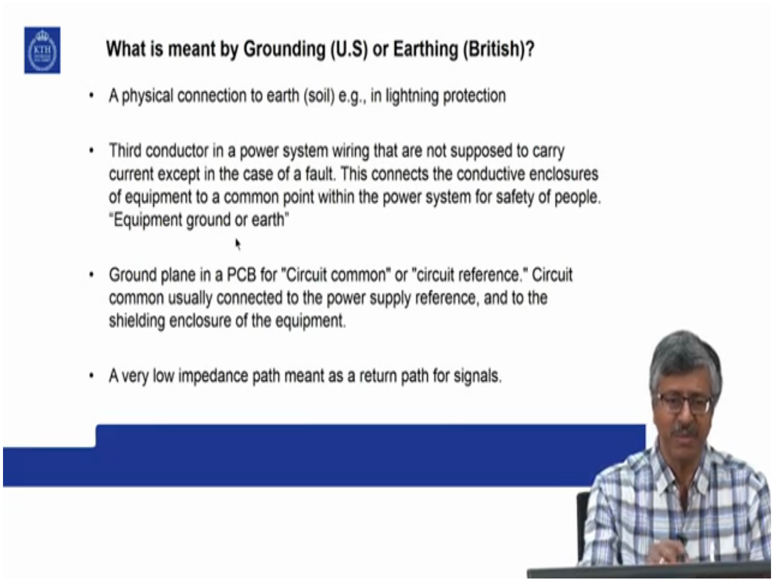

So what is meant by ground? So in the US people tend to use grounding, whereas in British or in UK people tend to use earthing, so often you can find both terms in the literature and both has more or less similar meaning. If you are looking at lightening protection there often grounding means a physical connection to earth or the soil because you need to drain most of the lining currents away from your building or the structure and safely away into the earth.

But often in EMC you do not require a physical earth for grounding, so there grounding is more like a third conductor for example in a power system wiring this third conductor is not supposed to carry any current except in the case of a fault. So this third conductor connects the conductive enclosures of equipment to a common point within the power system and this is mainly for the safety reasons for the safety of the people from electrical shock.

So this is often called equipment ground or earth equipment earth. Now ground plane in a PCB is a circuit common or circuit reference and this is usually connected to the power supply reference and to the shielding enclosure of the equipment. Sometimes grounding is also meant as a very low impedance path used as a return path for signals. So you can find all these four variations of definition when we discussed about grounding. So from the context you will know what is being meant.

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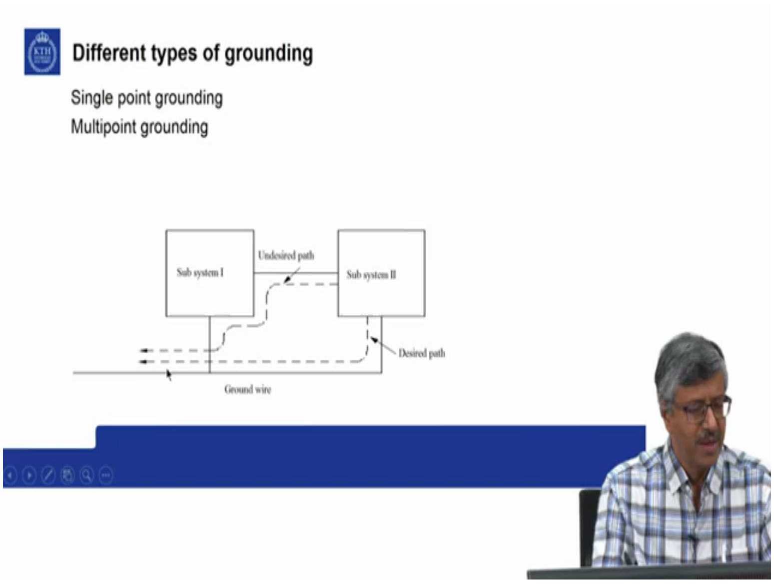

So two different types of grounding are often introduced one is single point grounding and other is multi point grounding. For example if you have a sub system 1 and sub system 2 there may have some connections between them and during any fault the desired path that you would like is along this straight to the ground wire, you do not want for currents to follow along the cables from system 2 to 1 and then from there to ground. So how do you ensure that all the currents are following straight to the ground all the fault currents not to the other system?

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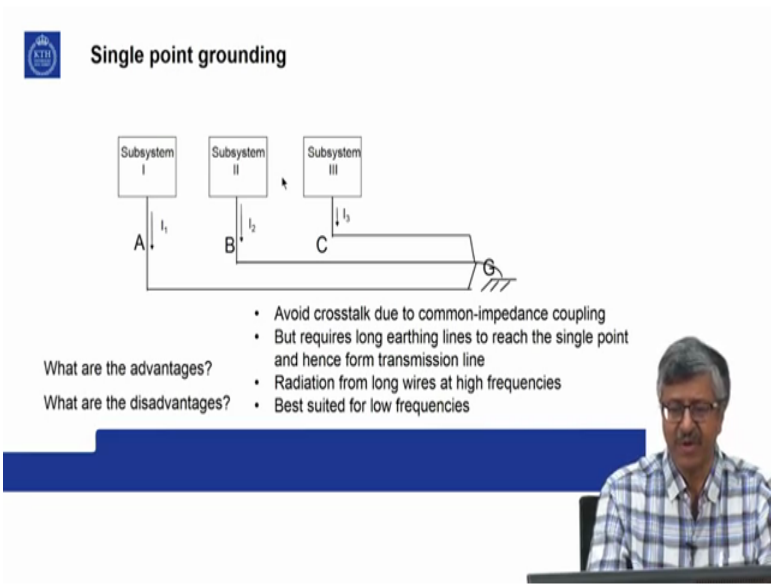

So single point grounding can often achieve that so here illustration is given we have sub system 1, sub system 2 and 3. So we have certain currents I 1, I 2 and I 3 during fault and going to the ground. Now what are the advantages of this type of scheme? One scheme is obvious in chapter 4 while talking about cross talk or near field coupling (you might have) you have come across common impedance coupling when from different sub systems currents are sharing a common path you have a resistive drop like voltage sag in a power line and that will interfere with the other circuit.

So that type of there is no common impedance between the systems in the ground circuits so you avoid common impedance coupling that is one big advantage of single point grounding, but at the same time if you want to bring your ground leads all the way to a single point you often require long lines because this may be physically large systems and you require long lines and depending upon the frequencies involved for the fault currents it may form transmission lines.

And you have seen in chapter 1 while discussing about transmission lines under certain conditions and certain frequencies they can oscillate between high impedance and low impedance the impedance of the transmission line is not constant, it can vary between high and low and that can create lot of problems and also at really high frequencies you have lot of radiation because this may be electrically long and you can have lot of radiation phase coming from this grounding leads.

So for this reason single point grounding may not be best suited for higher frequencies, it is best suited for low frequencies so that is where most of the single point grounding will be done. Then there could be another danger also especially during lightning strike and all if this is too long lines you can have a potential difference between these systems, so you need to really think of bounding between them in those type of cases using spark gaps or something like that, when we discussed about lightening protection we will go through that.

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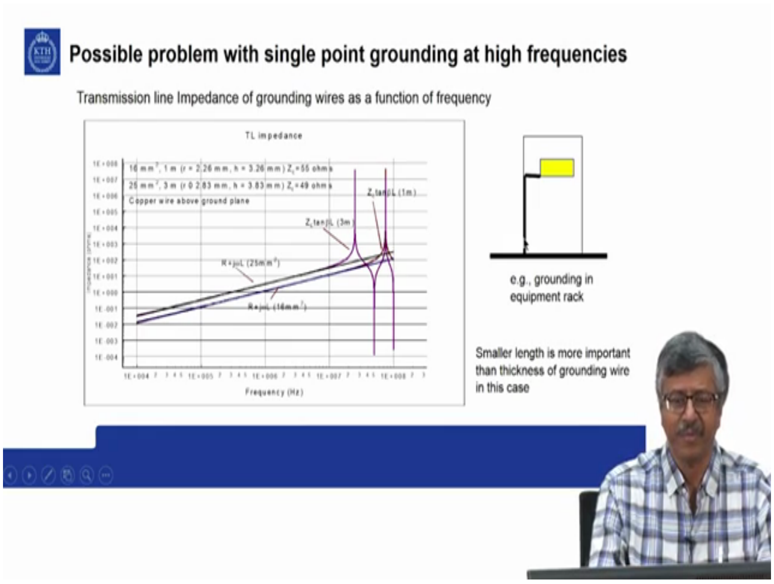

So this you have seen previously but it is again shown just to illustrate one problem that one might (encore and) encounter with single point grounding or with long ground leads in this particular calculation one equipment is grounded using two types of conductors a 3 metre wire of 25 millimetres cross section and 1 metre wire of 16 millimetre cross section and its impedance is calculated and it is shown the resonance peaks and resonance (())(7:48). So beyond around few tons of megahertz already this become unusable, so this we have seen before.

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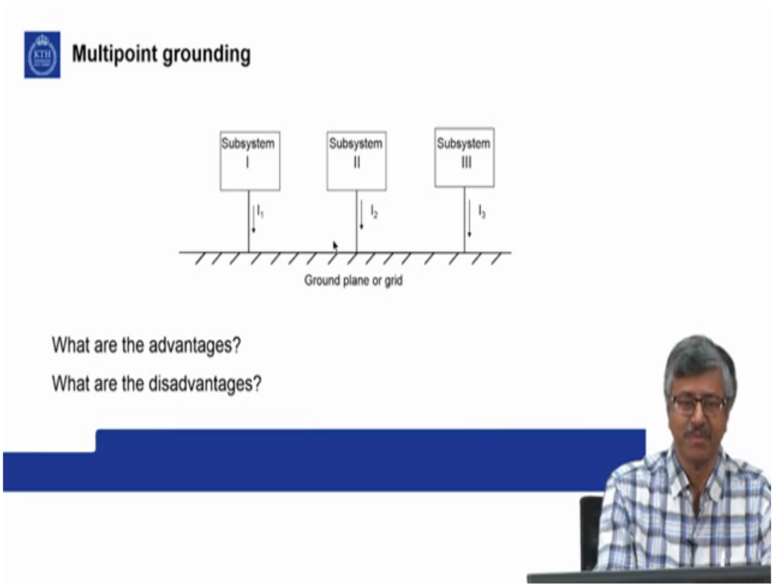

Now multi point grounding, some of the bad effects of single point grounding can be avoided by multi point grounding. So there the ground is a plane, not a single conductor it is a plane or a closely packed grid conducting grid where you have several sub systems arranged and connected to those with extremely short leads, so all the currents are going directly to the ground points and these currents are you do not form any common impedance path between these currents because there are so many paths that you can follow, not a single path.

So the advantage is that you avoid many of the radiated indifference problems from long leads and common impedance coupling can be avoided, disadvantage could be that if you have an external transients coming into the ground plane then it can create some problems. Say for example a fault current happening in some equipment outside of the system and a huge current is following along the path then you can have some common impedance coupling and all, but otherwise this is quite suitable for high frequencies grounding of high frequencies.

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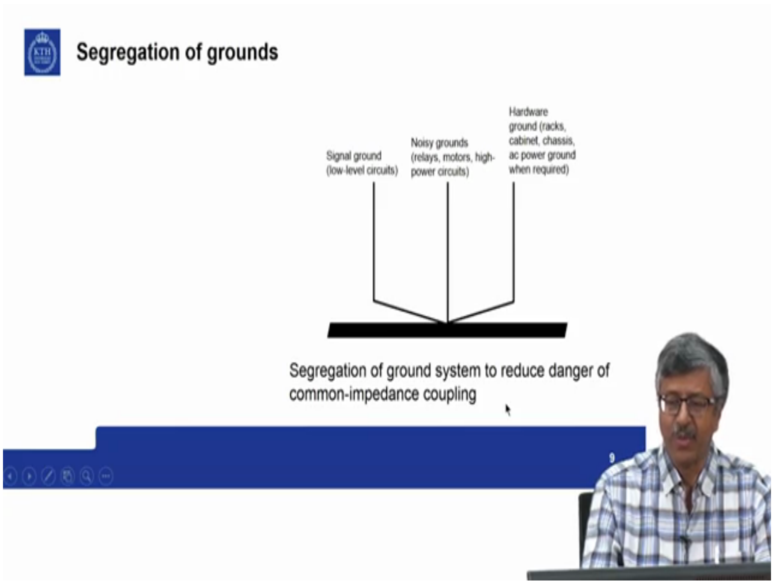

Segregation of grounds, now here you can have several type of grounds say for example signal grounds which are very low level, you have noisy grounds from relays, motors, high power circuits, etc where the currents are fluctuating and you have hardware ground where normally you do not carry any current but only under fault conditions. So you segregate those grounds and connect only at a single point because you do not want the noisy relays and motors contaminating your signals and creating problems over there by you know changing the reference of the signal ground.

So you connect all those things to this main ground only at a single point again to reduce the danger of common impedance coupling.

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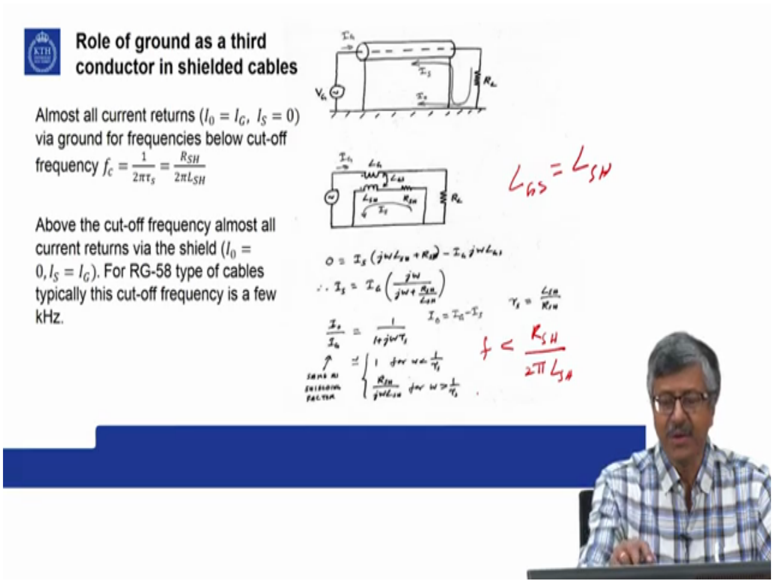

Now in shielded cables ground often appears as a third conductors if you have a shielded cable along the close proximity of a reference and if you have certain currents in it you have seen in the theory for shielded cables that beyond certain cut off frequency almost all the currents will be returning via the shield, not via the ground even though shield is connected on both sides to the ground most of the currents will be returning the shield.

So this you can see from the principle of flux minimization or appear mathematically you can have a circuit diagram like that and find out that most of the currents are returning through that. Say for example let us say at very low frequency that is frequencies below cut-off all the currents will be returning via the ground and above the cut-off frequency all the currents will be returning via the shield.

Now this is an equivalent diagram for this cable, so L G is the generator wire this middle wire the self-inductance L GS is mutually inductance between receptor wire and the shield and L SH is self-inductance of the shield so there are three inductances involved, two self and one mutual and the coupling is shown here the shield is having some resistance and this is the load R L.

Now if you by the loop equation, 0 equal to I S times j omega L SH, so we are taking this shield loop plus RSH, then a source that is a series voltage source due to this mutual coupling which will be opposing this original flux so it is minus I G j omega L GS, so this equation you have seen before. Now manipulating you can say that L GS is equal to L SH because it is very tightly coupled system, so L GS equals L SH mutual inductance between the inner wire and the shield is same as shield self-inductance.

So with that simplification (())(14:39) we can get that I 0 by I G which is same as shielding factor equal to 1 by j omega tau S where tau S is shield inductance divide by shield resistance, so this you will get. Now you can have two conditions this will be approximately equal to 1, if omega is for less than 1 by tau S so when this part is almost negligible and this will be equal to 1 by j omega TS or R SH by j omega L SH or omega for greater than 1 by tau S. So this is for high frequencies, so this is corresponding to frequency below cut-off below R SH by 2 pi L SH and this is above that. So here you see how the ground is functioning.

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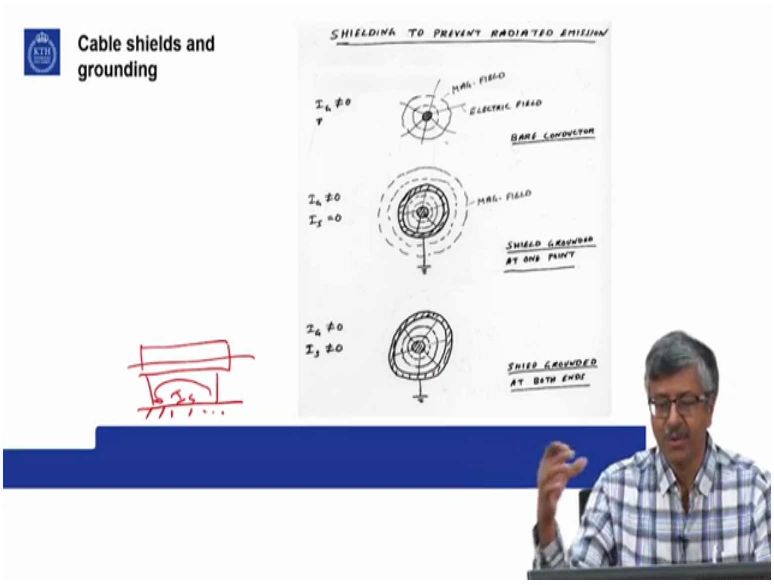

Cable shields and grounding, often shielding can be used cable shield can be used to prevent radiation radiated emission from the shield from the wires signal wires. So if you have a receptor conductor inside and a shield outside and if there are no shield currents then all the you have electric field and magnetic field penetrating outside the cable shield because there is no current on the cable shield.

So this is just a bad conductor, so it does not matter where you have a shield or not as long as they are not connected anywhere as long as the shield is not carrying current it is not having (())(17:07). But in the second case the shield is connected to the ground at one point then atleast you are shorting out all the electric field and only the magnetic field is penetrating outside still there is no shield current but in another case both ends of the shield is connected.

So if you have a shielded wire like this you are connecting both ends to the ground, then you have a circulating shield current so I S is not equal to 0, so in that case you are confining the magnetic field also to the inside of the shield so you are not letting out in magnetic field outside. So shielding can be used to prevent radiated emission from cables, so this is one of the reason why shielding is provided to cables. So this is two way, it can also prevent this inner circuit from being effected by external phase, both sides it works.

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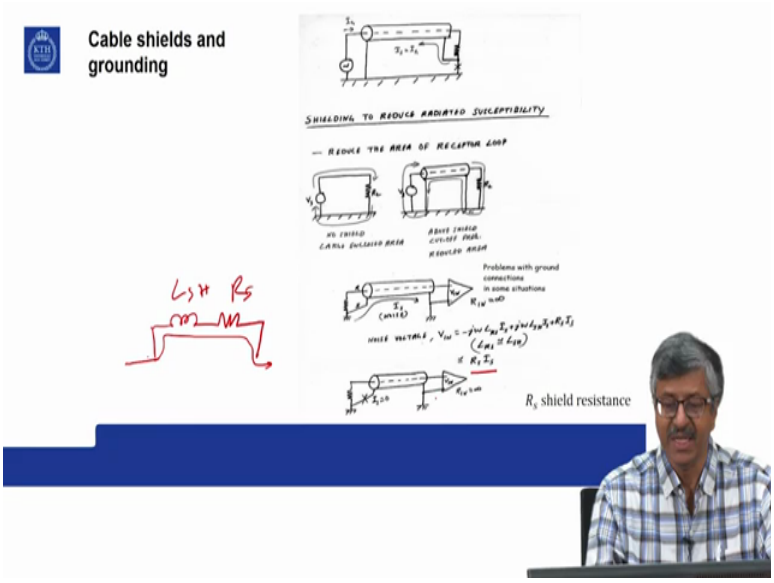

So again we will look at to cable sheets and grounding, shielding to reduce radiated susceptibility, so this part is grounded instead of to make sure that all the current is returning to the shield you ground only on one side and you can connect this end to the shield, so this may be more effective sometimes. This is no shield and this is shield about shield cut-off frequency, so you can say that this is very large area being presented for external fields now you are presenting very small area so that way also you can see it.

But sometimes if you have connections at both ends it can create some problems so you cannot do mechanically connection I mean without thinking on both sides. So one case is illustrated here, suppose you have a amplifier or something where some signal is fed using a shielded cable because of some external noise you can have a circulating current like this around the cable shield and this will create a drop.

You can imagine the shield circuit you have a shield inductance and shield resistance so the current is coming through and going out like this. So if you write this voltage drop equation minus j omega the mutual inductance I S plus j omega shield inductance L SH and this is R S

I S, so we have seen before that self-inductance of shield is equal to the mutual inductance between the signal wire and the shield approximately.

So this will need the input voltage to the amplifier as resistance drop times the noise current sorry this is the not resistance drop it is the drop across the shield resistance times the shield current. So this quantity R S I S resistance drop so this noise voltage will be super imposed on the signal, so R S is the shield resistance. So preferably you need to avoid this connection in this case, so there is no uniform way of applying certain principles you have to really analyse the situation and see if a measure that you take to avoid EMC problems will (()) (21:57) this situations or not? So we have to think very intelligently.

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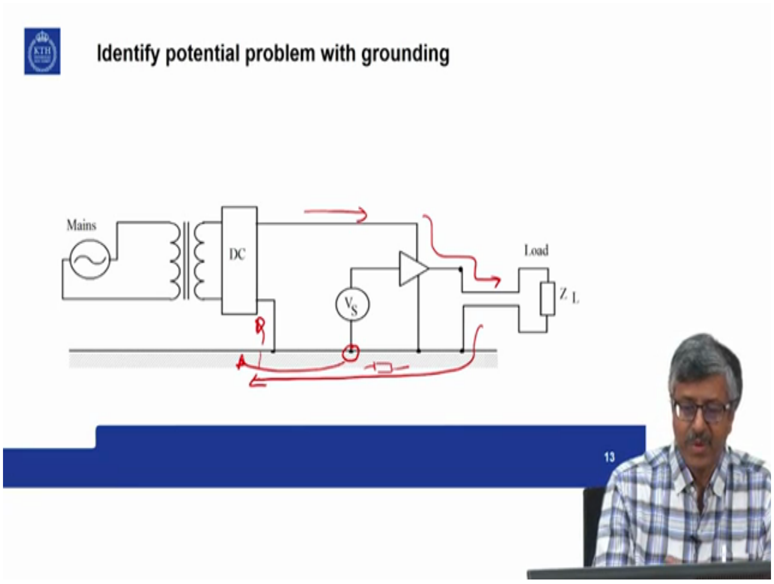

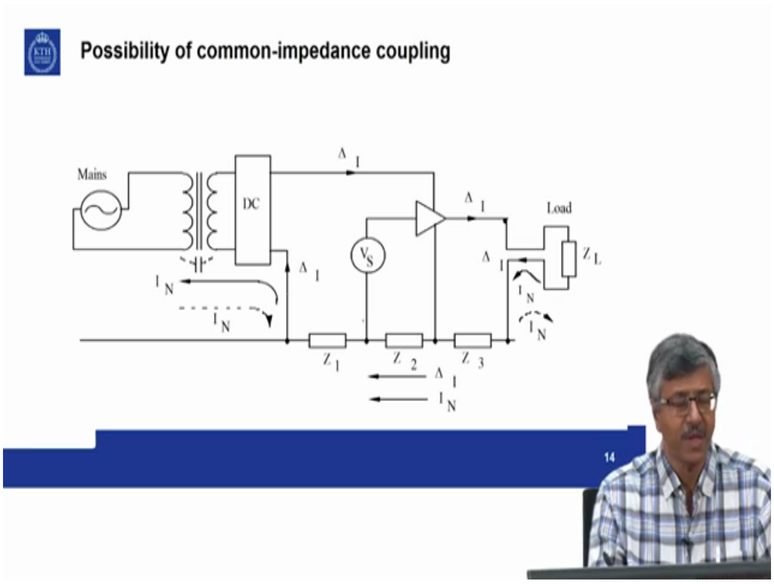

Now another problem is illustrated here to show the importance of thinking through and rather than just apply mechanically some measures. For example this is an amplifier amplifying a signal, so in this case the heavy currents are flowing like that then returning back to the transformer like this. So this signal is amplified so it may look perfect circuit but it can create lot of problems because you have a common impedance here this grounding and when heavy currents are flowing it is creating common impedance and this is the reference.

So you create a voltage drop across this and this voltage drop is super imposed on the signal so your output will be completely destroyed. So you need to remove this connection from here and may be connect it somewhere here so that you are you know away from the path of this current, so then there is no common current between this and this point, so all the currents are traced out here, you can have noise from the load also that also will create a common impedance drop across this.

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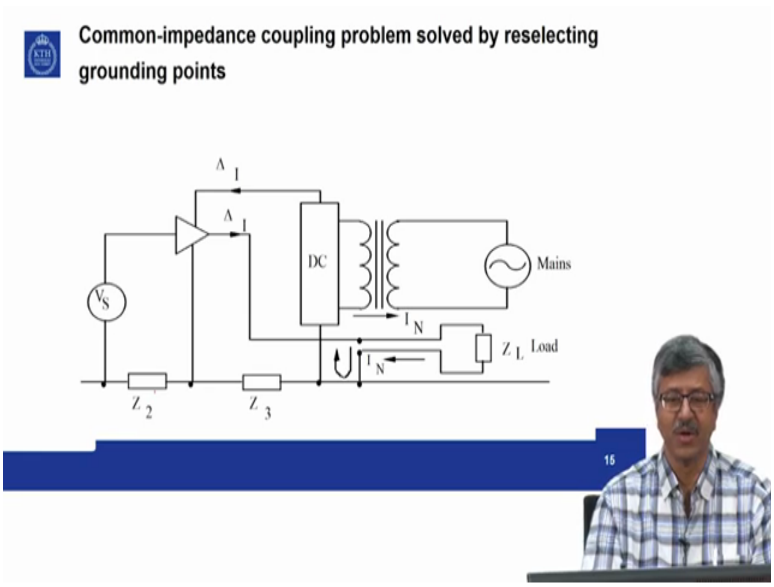

Now here the solution is effected now in this particular way remember there is a common impedance there is no current flow through this because all the noise currents and others are returned via this directly over here so you do not have any current flow through set C or set 3 or set 2. So in this way by simple rearrangement of the connections to the ground you can solve this common impedance coupling problem, so that is end of module 2.