Power Electronics with Wide Bandgap Devices
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Lecture-20
Electromagnetic Interference (EMI)

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Welcome to the course on power electronics with wide band gap devices. Today I am going to discuss about electromagnetic interference and electromagnetic compatibility.

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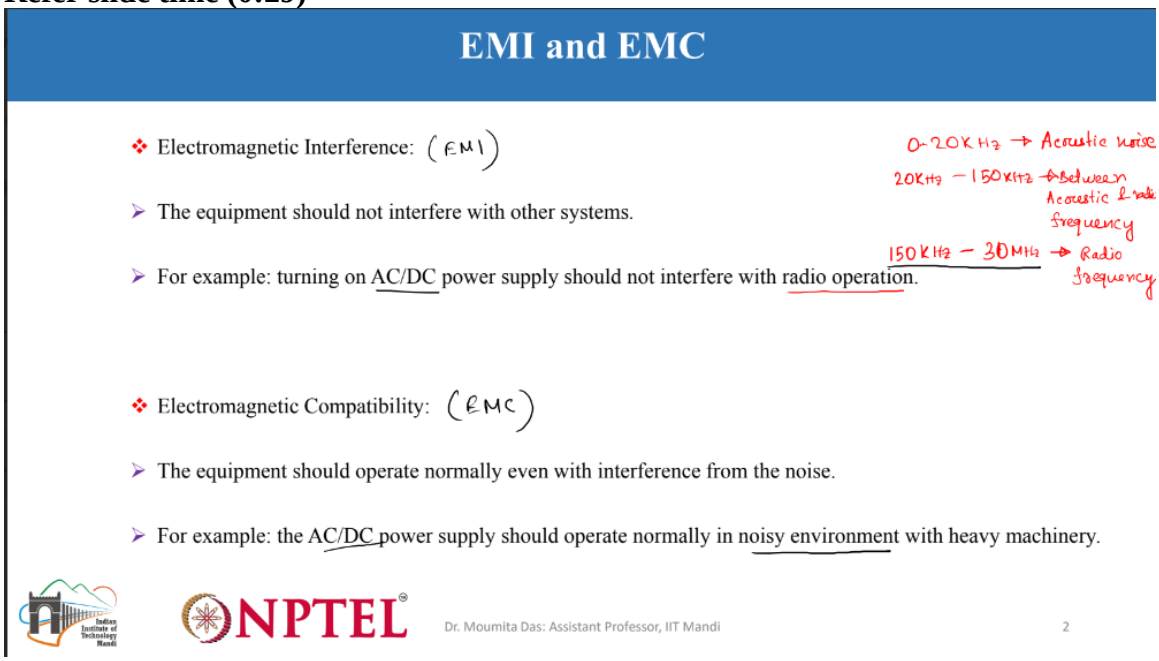

Say about electromagnetic interference or electromagnetic compatibility, we first have to know how these problems are coming. So as you can see in this particular slide, it is written electromagnetic interference which also known as EMI. So it is basically the equipment should not interfere with other system. Suppose we have any equipment.

Let's say an example of one laptop. So that equipment or laptop whenever it is on. So it should not interfere with other laptop which is placed next to it. So, for an example, you can see here, so turning on an AC to DC power supply, in any equipment the power supply will be there, right.

So, this AC to DC power supply should not interfere with radio operation. So, what is this

radio operation? So, when we say this radio operation, it must be in particular frequency range. So, what are these frequency ranges? So, we know about different frequency ranges. So, let us say the frequency range 0 to 20 kilohertz, 20 to, so 0 to 20 kilohertz. In this frequency range the noises which are present that are known as acoustic noise.

Now when the frequency range is between 20 kilohertz to 150 kilohertz. So then the frequency is between acoustic and the radio frequency. Now when the frequency is between 150 kilohertz to 30 megahertz that time it is known as radio frequency. So, this is just to give you an idea about like what is the level of frequency we need to consider. whenever we considering EMI noise.

So, as you can see here, so it is the interference with radio operation, radio frequency operation and what is the frequency level? That is the frequency is between 150 kilohertz to 30 megahertz. So, now like whenever we have considered lower frequency operation let's say 0 to 20 kilohertz frequency operation of the converter. So, that time this problem was not severe, but now due to the wide band gap devices introduction in the power industry. So, this frequency level is increasing. So, now we are expecting the frequency of operation of the wide band gap devices let's say silicon carbide or gallium nitride it will be higher higher means for silicon carbide it will be let's say around 150 or 200 kilohertz for high power applications and for gallium nitride it is expected to be in megahertz So, then when we are operating in that frequency level it is coming in the radio frequency range.

So, the noises which will be generated due to this EMI. So, basically electromagnetic interference it will also be in that particular range. So, the interference will be there. So, earlier the lower frequency operation there were different advantages and disadvantages of low frequency operation. So, there the cause of this interference was there, but due to low frequency operation this interference was not severe, but now due to high frequency operation of the semiconductor devices this interference will become part of the switching operation.

So, that is why we need to worry about this kind of noises and we need to see what kind of noises are present and how to mitigate them for converter operation. So, now this is with respect to the EMI. Now, what is electromagnetic compatibility? So, the full form of electromagnetic compatibility which is known as EMC. So, basically EMI is the reason. So, basically equipment should not interfere with other system, any converter which is placed.

Basically is the equipment should operate normally even with interference from the noise. there will be interference. So, we have to make the system electromagnetic compatibility

so that even if there is a noise present then also the equipment should operate properly. So, you can see the example and the AC to DC power supply should operate normally in noisy environment with heavy machinery. So, this AC to DC first we are saying this should not interfere with radio operation, right.

And then even if that interference is there, the equipment should be able to operate properly that is electromagnetic compatibility. So, there these are two different things, right. So, let us see in details how we can actually classify them.

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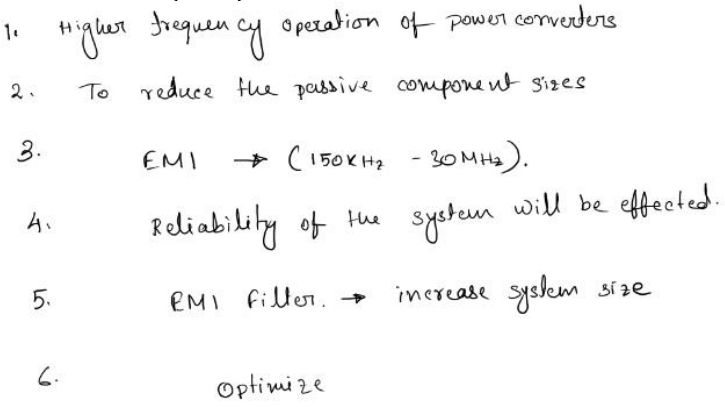

So, basically when we say electromagnetic interference, so what is the reason of electromagnetic interference? So, when this, the reason, the first reason is that higher frequency operation of the power electronic devices. So, higher frequency operation of power converters.

So, this is what we are actually trying to look into. So, basically whenever there is a higher frequency operation in power converter, so then what is happening? So, the converters moving towards high frequency operation region to reduce the passive component sizes, to reduce the converter size or passive component sizes. So, this is a very good thing for the system level size reduction. Now okay fine, so this everything is moving towards high frequency region and also due to the development of this wide band gap devices, it is possible to implement that kind of system. So, now once we are moving towards that particular region, then what is happening is that there is a increase in the noise or the EMI.

which is in the range of 150 kilohertz to 30 megahertz, right. Now, you can find this EMI

is increasing. So, then what? Then it will affect reliability of the system. Reliability if it is getting affected then we need to worry about this. Then what we have to do? We have to provide a solution to mitigate these noises and that solution is possible by using filter.

So, that is why we need EMI filter. So, there is a filter to reduce the noise we can use the filter. Now, what is the problem? So, if we are using filter then again we are increasing the size of the system right. So, that was the main motivation to go for high frequency operation. Now, we are at high frequency, but there is some other problem and to reduce that problem again we are introducing some filter or some additional component and this additional component again will increase system size, right.

So, this will cause, this will, so this will increase So, then what we have to do? So, we have to see how we can optimize the system operation or means operating frequency and also optimize the filter. So, that the system size will not be higher, but it will also not have higher level of noises by using low value of the filter, right. So, this is the thing we need to look into, okay. So, now these sources of EMI what are those?

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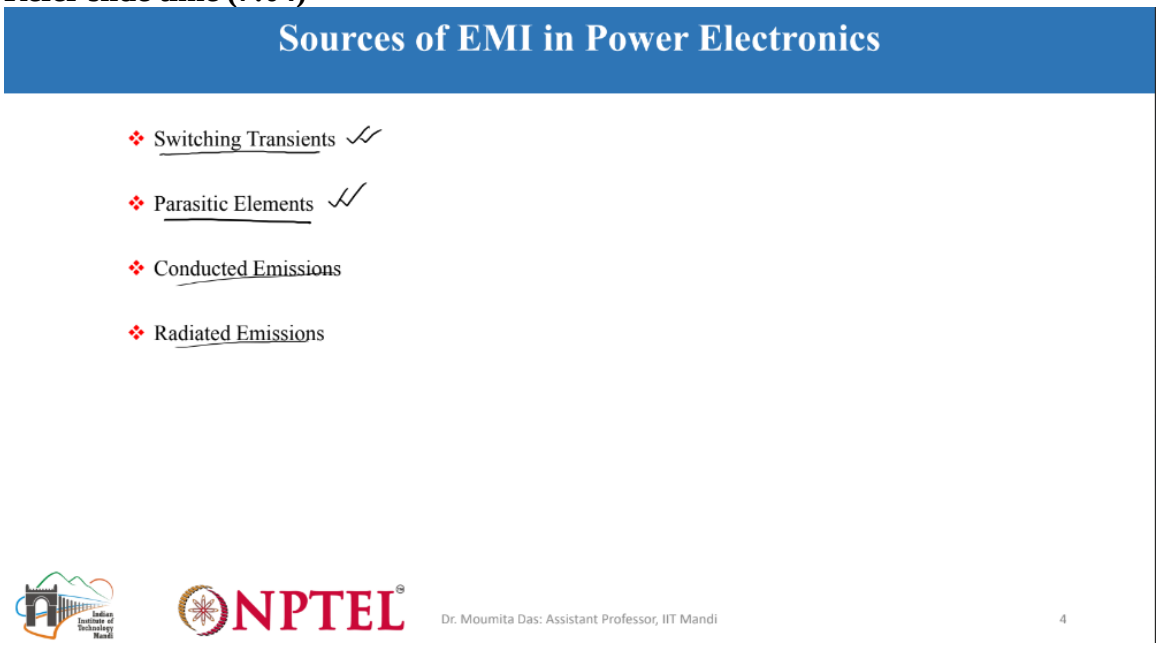

So, basically if you consider any power electronic system, the main component is switch which is the which is basically heart of the power electronics system. So, then these switches will cause switching transients to be present and this switching transient is one of the main reasons of the EMI noise.

So this is the main reason. So there are additional reasons which comes from the parasitic elements. So the parasitic elements anyway like it is part of the system. We can try to

optimize it but we cannot completely remove it. Now these two comes from the circuit itself or the converter itself.

Now there are other two factors which affect EMI noise. First is the conducted EMI and second is the radiated EMI. We will see in details of these two EMI noises, how these noises are coming and what are their paths and how we can calculate noises in this particular two different methods. So, that we will see later in this particular discussion. So, now when we say this EMI in the power electronics, conducted EMI.

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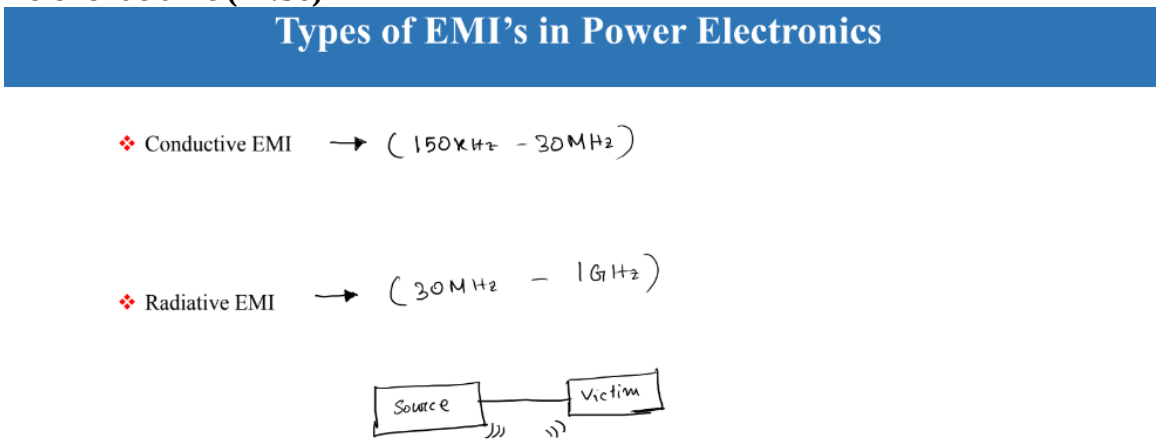

So, the conducted EMI when we are saying, so that is in radio frequency level. Means this noise is present gently in the range of 150 kilohertz to 30 megahertz. This is the range, this particular EMI, conducted EMI. When we say radiated EMI, so this is generally in the range of 30 megahertz to 1 gigahertz in this particular level. So, these are two different noises, conducted EMI basically it comes by the conduction path so it the path can be through any parasitic component any parasitic capacitance inductance any path which is present in the circuit itself which may not be the actual circuit path so that path provide the like conducted emi noise path okay but radiated emi how it is coming so basically if there is a source present right then source is connected to the system.

So, let us say we are calling the system as victim because it gets affected. So, now this source will have some radiation. So, EMI, so basically this radiation EMI will be coming from the source and this will affect the victim which is placed next to it. So, in this

particular kind of noise, so actual path need not to be there to affect the system. So, it will be through the radiation.

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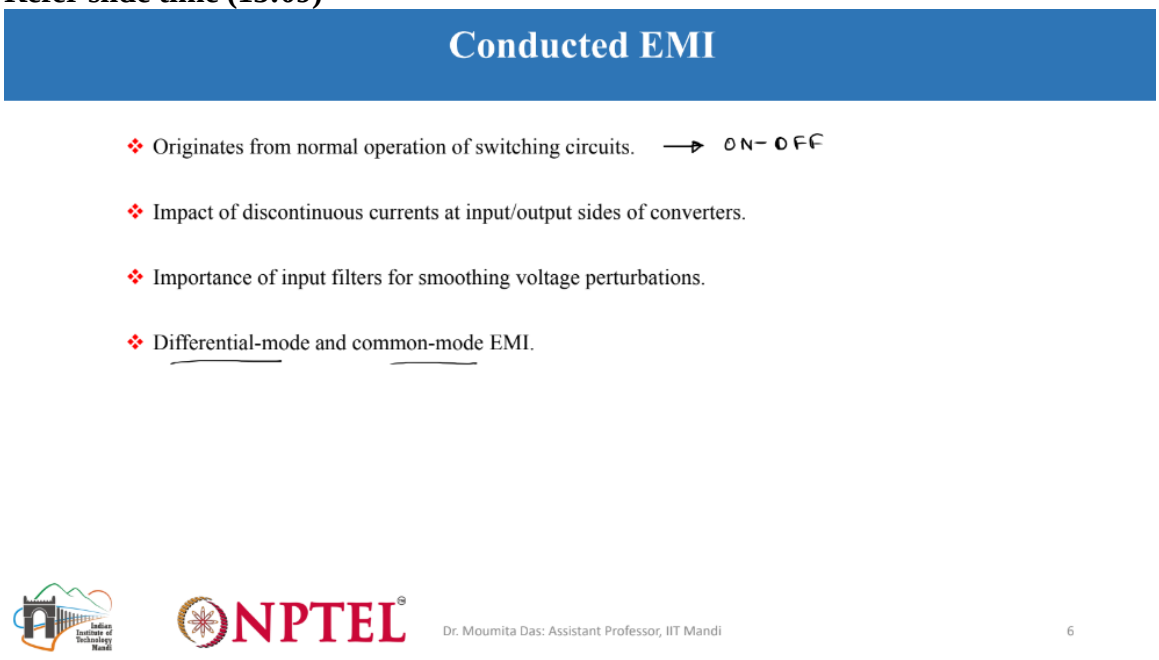

So, radiation which is coming from the source which will affect the victim. So, now this conducted EMI how it comes? So, basically it originates from normal operation of the switching circuit. So, means normal operation means on or off operation of the switching circuit. So, then what happens? when switch is turning on or switch is turning off, the converter circuit principle is changing. So, basically circuit structure when it is in on state and when it is in off state, so they are different.

So, that will cause this conducted EMI to be present due to change of the circuit state. Then impact of discontinuous current at the input and output sides of the converter. This is also coming due to change of states in the switching operation. Then it is important to connect filters for smoothing the voltage perturbation. So, generally if you see any converter input there is a filter capacitor.

is presented. So, basically the reason is that this input capacitor it smoothens the voltage perturbation due to the switching transient of the converter operation. The differential mode and common mode EMI. can be present. So we will see about this differential and common mode EMI. So basically conducted EMI can be categorized in two types.

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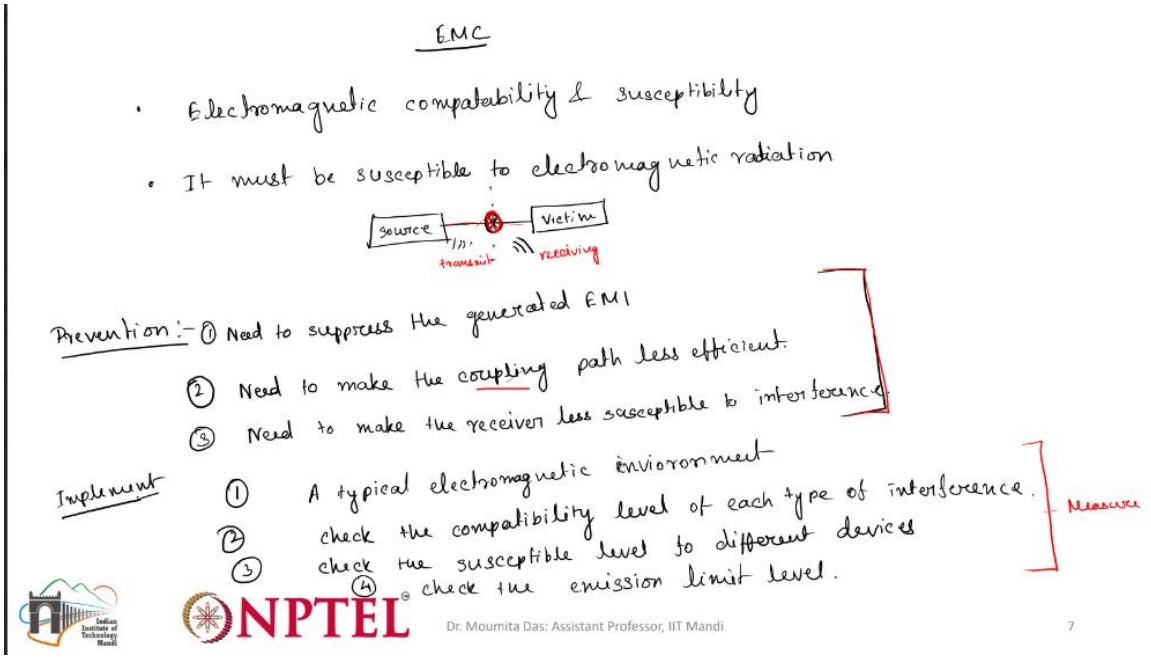

One is differential mode and another is common mode. So these two types of EMI can be present in this conducted EMI. So now this is with respect to the electromagnetic interference now if we see the electromagnetic compatibility so basically what happens so so it is actually it covers this electromagnetic compatibility and susceptibility. So, basically what happens? So, whenever a system is present, we have to make sure that is electromagnetic compatible. Even if there is a noise present around it, the system itself should have the filter or some medium which can protect the system from the noises.

Even if in the noisy environment, it should be able to perform perfectly So, that is known as electromagnetic compatibility and susceptibility. So, basically it must be susceptible. So, the system must be susceptible to electromagnetic radiation. Now as I have shown in the previous slide so basically if the source is there and it is having some electromagnetic noise which is coming due to radiation and the victim is placed here. it will get affected from this particular noise.

So, then we have to provide a filter or some medium in between source and victim so that this noises will not affect the victim. So, basically this noise will get cut off. due to the presence of the filter or the medium so that victim will operate properly even the noisy environment okay so now we can also classify this electromagnetic compatibility in different types so what are the classification of this electromagnetic compatibility so electromagnetic compatibility so i'm writing this in short form so it is actually having two

different types So electromagnetic susceptibility and then electromagnetic emission. So this is electromagnetic susceptibility.

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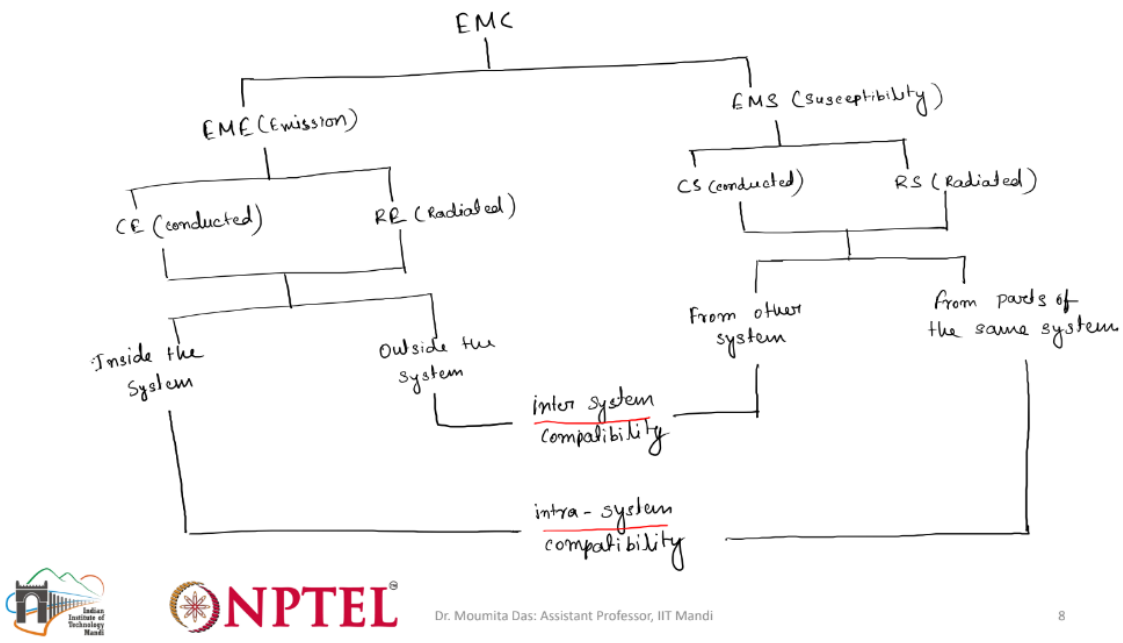

This is with respect to susceptibility. So I am just writing the short form. And this is with respect to the emission, electromagnetic emission. Now this electromagnetic susceptibility again can be classified into two types. So that is conducted susceptibility.

So just write this. Conducted susceptibility and radiated susceptibility. And this can be divided in two types again. Conducted emission. and radiated emission.

So, here C is for conducted. So, I am just writing the one. So, C full form is for conducted and then R is for radiated. Similarly, it is for radiated. and then conducted. So, now both again can be classified here as two different types.

Inside the system, one is inside the system Another is outside the system. This is from other system and this from parts of the same system. So, you can see here this EM, so this EME, so which is classified in conducted emission and radiated emission, it can be classified in two types inside the system and outside the system. Means this emission can come from the system itself or maybe it can be affected from the outside the system. Means let's say if the system is having multiple switches or the multiple like you can say steps.

So part of it can affect the system itself. So noises of one step can affect the noises in the

second step. Okay, so similarly the susceptibility it is basically it can actually, so it is again divided in two types, conducted susceptibility, radiated susceptibility. So, it is again divided in two types from the system and from other system from the same system. Means, it has to be susceptible if like the any other system is placed next to it. So, then due to the presence of the radiation of that particular system, the system should be susceptible or it may happen the system itself is having some radiation which may affect some part of the system.

So some part of the system is the reason for creating the radiation and some other part it may get affected. So then it can be called as the either inside the system or from the system itself. So we have to make sure that like one part of system should not get affected from the other part of system. Similarly as one system should not get affected from the other system which is placed next to it.

Okay. That is why it is known as intra system. So this is known as inter system. So between two system compatibility. And now if it is so basically from other system so means like it is from the other system it should not get affected. So inter system between two system this compatibility should be there. Now if it is within the system itself like some part of the system inside the system is causing the this electromagnetic radiation and that may cause damage of the some other part.

So then we have to make sure that is also not happening and that is known as intra system compatibility so basically both cases so you can see here this is inter system and intra system both is significant in this particular case So both should be taken care properly. Okay. So now I will just come back to this particular slide in order to, so this classification, after the classification I will just tell you like how we can prevent this. So what is, what are the methods of prevention? These problems are there.

At high frequency these problems will get much more worse. So what we have to do? We have to provide solution. We have to find out what is the level of the noise, what is the magnitude of the noise. We have to provide solution accordingly. So now the prevention, how we can provide prevention? We can provide to suppress noise. the generated EMI so we need to need to suppress basically I get this right from here so first point is the need to suppress the generated EMI second is that is that need to make the coupling path less efficient.

So, previously I have discussed about coupling in PCB, right. So, their coupling can be inductive, capacitive, any other thing, magnetic. So, here you see this link between source and the victim, this is the coupling path. So, what is connected between source and victim. Like whatever coupling path is causing this radiation or maybe noises to actually like go

from the source to the victim.

So that path we have to make less efficient. So that part can be anything like capacitive, inductive. or magnetic anything whatever is causing that path to be present so that is known as the coupling path you know like that otherwise the victim will not get affected so that path we have to make less efficient so we have to see how to do that okay now third is that need to make the receiver so here which is the receiver in this particular block diagram the receiver is the victim okay this is the transmitter so basically so the point it is actually transmitting and this is the point where it is receiving so receiving is the victim or we can say the power converter So we need to make the receiver less susceptible to interference. Okay. So that these points we have to make sure in order to prevent the system from the this electromagnetic noises, okay. So, now how to actually realize those things? So, basically these are the things we need to look into.

So, then how to actually implement this? So, then that is possible by using so basically we have to create a electromagnetic a typical electromagnetic environment second is the we have to see the compatibility level check the compatibility level of each type of interference. okay so we have to check that first we have to create the environment then we have to check the compatibility level okay now third is that we have to see check the susceptible level for different devices and then last is the check the emission limit level. okay so basically what we need to do so basically first we know the type of the different noises in emi or emc what can be the type of different noises it can be from the system outside the system and emi it can be conductive radiating all this thing up when we have the information then what we have to do we have to prevent those right we know that we have to prevent those different noises now how to prevent those first we have to measure basically in order so basically this is the prevent so basically we have to measure the noise level so either it is like conducted differential or maybe radiated kind of emi what is the noise level so in order to measure that we have to create that electromagnetic kind of environment there we have to check the device noise level and then we have to see the susceptibility of the device the device how in how much noise it can operate properly what is the susceptibility level of the device so then everything once we have the information once we measure all this thing then we can say whether the device is operating within limit or the noise level in the system is above the limit so once we check that then only we can decide like whether we need to provide filter or the present like whatever noise is present in the system that is okay for the device to operate properly so if we need to provide filter then we have to go for designing of the filter okay so next what we will be discussing we will be discussing about like what is the measurement technique how we can measure different noises So, what are the different noises in EMI that conducted or like common mode noise or the differential mode noise. So, what are those noises and how we can measure those noises.

So, more about this I will be discussing in the next class. So, these are the references. Thank you.