Electromagnetic Compatibility
Professor Rajeev Thottappillil, Daniel Månsson
KTH Royal Institute of Technology, Sweden
Module 1.1
Introduction to EMC - Definitions

Welcome to this course on electromagnetic compatibility or EMC in short. This is offered by KTH Royal Institute of technology in Sweden and the course lecturers are Rajeev Thottappillil, which is myself, and my colleague Daniel Månsson.

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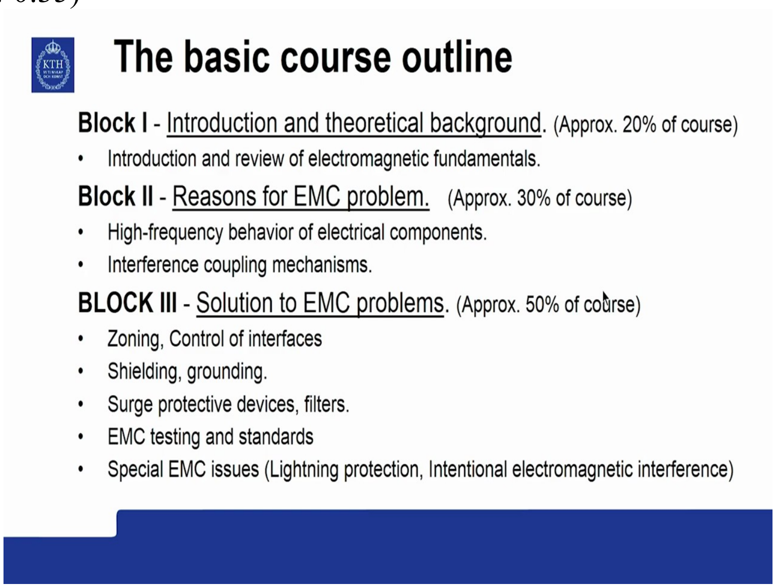

You have seen the introduction video regarding this course which gives a brief description. Now within this course, the contents can be divided into 3 blocks. Block 1 will describe introduction and theoretical background and block 2 will describe why there are EMC problems, the reasons for that. Block 3 will deal with solutions to EMC problems. Now the course is designed in such a way that on block 1, that is, introduction and review of electromagnetic fundamentals, we will spend approximately 20% of the course time.

And for block 2, on high-frequency behaviour of electrical components and interference coupling mechanism, we will spend around 30% of the course time. Around 50% of the course time will be devoted to describing various solutions to the EMC problems. These solutions can be different types of measures like zoning, control of interfaces, shielding, grounding, surge protective devices and filters. We also will deal with EMC testing and standards, a short introduction to that and some special EMC issues.

You require some specific kind of measures in certain situations, for example, protection against lightning phenomena and intentionally created electromagnetic interference.

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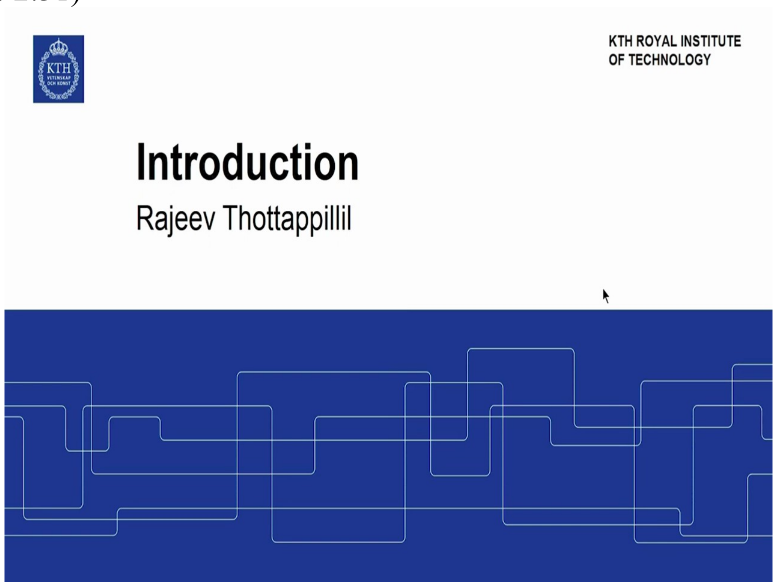

First we go to introduction. This will be given by me.

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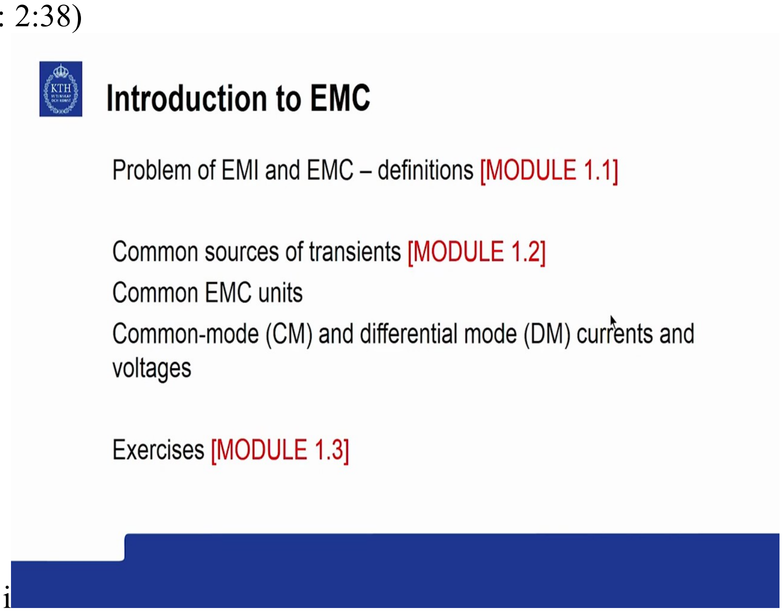

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This chapter is divided into 3 modules. In module 1, we will go through the problem of electromagnetic interference and define what is meant by EMC, how to achieve electromagnetic compatibility. In module 2, common sources of transients will be described, like switching transients, lightning, et cetera and we will talk about commonly used EMC units like what is meant by a decibel and what is meant by wavelength. Instead of meters, why do you represent in EMC studies, how many wavelengths long? Then what is meant by common mode and differential mode currents and voltages.

Module 3 will be devoted to some exercises and problems. This will be mostly in the form of home work that you can do at home so that you become very familiar with the concepts introduced over here.

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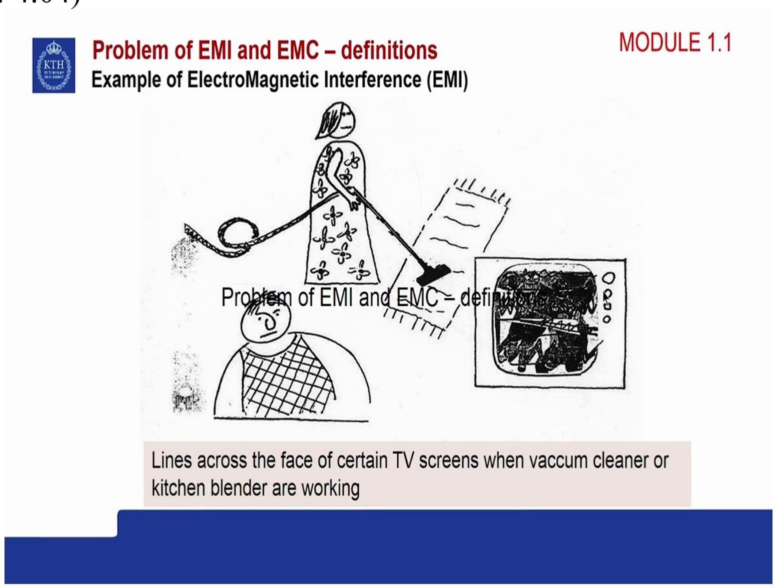

Now what is meant by the problem of electromagnetic interference? This particular cartoon was drawn by one of our student in the EMC class. Basically, it shows well you have a TV screen over here and someone is doing a vacuum cleaning and vacuum cleaner has got a motor there and if you had old CRT tube TVs, one could very clearly see lines on the TV screen and an annoyed partner over here. So you can see that the lines may be due to the disturbance created by the motor onto the CRT tube. This is one example. It can be a kitchen blender or any other or a drill, electric drill or anything having a motor can produce this type of disturbances. So this is a fairly less harmful form of electromagnetic interference.

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Sometimes in the early days of pacemakers, there were some worrying forms of interference. For example, when someone was talking over early versions of mobile telephones, it had interfered with pacemakers of patients. So that is more serious forms. Any of you travelling by airplane might have experienced lightning strikes to airplane while landing or while taking off. This is very common nowadays but in the early days of aviation history, it was a great concern. In fact, the branch of EMC owes a great deal to the need for protection of airplane from lightning strikes. Here we can see the challenge.

There are several millions of volt and several thousands of amperes in a lightning flash whereas modern electronics in the plane that is controlling the flight has withstand capability of only certain volts and a few, maybe microamperes or nano amperes. So how do we reconcile these huge differences in the amplitudes? That is where the method of EMC is coming in. The millions of volts and thousands of amperes of lightning currents outside the skin of an aircraft, by the time it reaches the sensitive electronics, it should be below a few volts and below nanoamperes. So how do we achieve this? This is what we will learn in this course partly.

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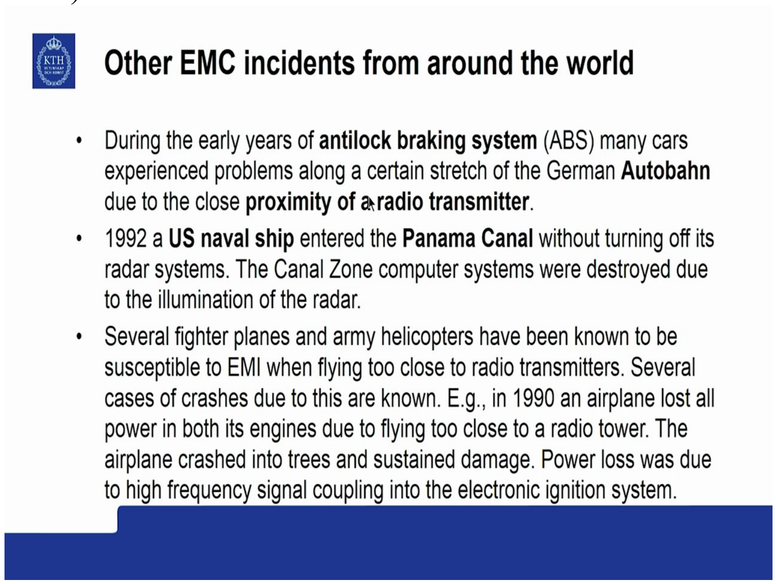

Now there are several other incidents of electromagnetic interference from around the world. Some of them are described over here. Say for example in the early days of anti-lock braking systems, there were several cars experiencing problems along a stretch of the German highway which had close proximity of a radio transmitter. And there was an incident of a US naval ship entering the Panama Canal without turning off its radar system and all the Canal Zone computer systems were destroyed due to the illumination of the radar.

And you can see several of these problems described here and you can find many of these types of problems by searching the web. Many of these types of problems have been since solved but new ones crop up every time a new technology is coming up. Say for example now there are a lot of talks of completely autonomous vehicles with lot of control functions being added and what role EMI or EMC will play in the design of those systems? hat is also a new type of challenge coming up.

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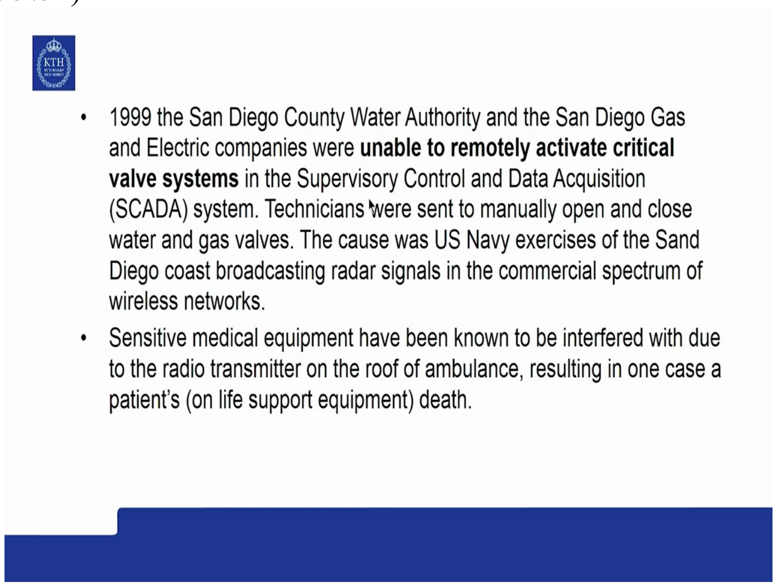

In the medical field, it has been known that several medical equipments are interfered with radio transmitters. It can be radio transmitters of the ambulance or it can be of the persons carrying it and often in hospitals, you have seen that mobile phones are prohibited from many rooms. It is not only the noise pollution from the sound but also due to the fear of electromagnetic interference, that is being done.

And while taking off and landing, all kinds of electronic transmitters or operation of electronic equipments are prohibited in airplanes and that also is prohibited by the fear of electromagnetic interference because during takeoff and during landing, there are so many systems working in the airplane that has to coordinate with each other. So glitches created by mobile transmitters inside the plane can cause issues and they want to prevent it and that is why you have the standard instruction of switching off all the electronic devices or putting it in the flight mode so that the transmitters are switched off.

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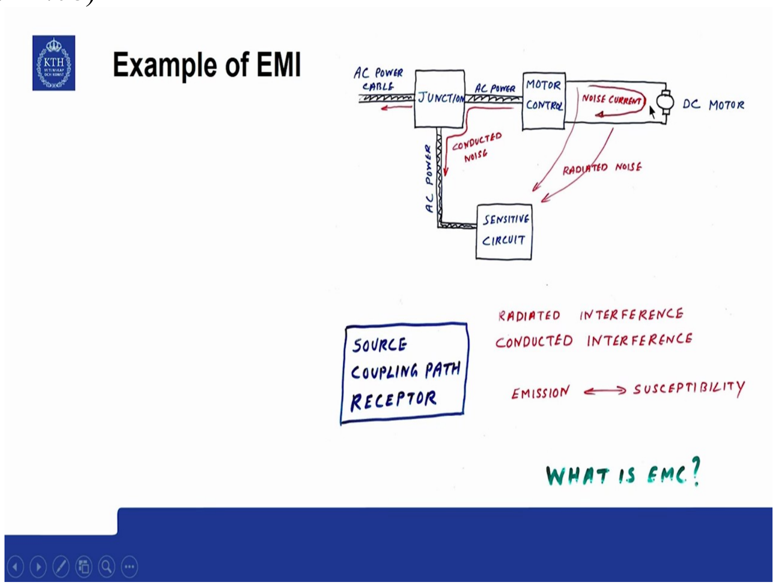

Now to define some of the terms, let us take this very familiar example. You have a motor that is working from the mains. Suppose this is a DC motor or a universal motor with brushes or something like that. Then there is the AC power cable, there is this junction, but this junction is feeding some sensitive circuits also, controlling some other things and there is motor control which involves switching by semiconductor devices with very fast-rising pulses. Now there is some noise produced in the motor due to the brushers and commutation. And there is some noise produced by the controls.

All this noise of various characteristics, part of it would be conducted along the lines and it can be distributed, through the AC power, to the sensitive circuits. And there is a potential for it to be disturbed. Then some of the noise, from these are kind of transmitting antennas, this wiring over here, will be radiating into the air and sensitive circuit would be picking it up and this will be called the **radiated noise**. So noise produced in one system, that is the source of this noise, can be coupled to another system.

Here, it is conductive coupling and or it can be radiatively coupled to a receptor or a victim where it can potentially produce disturbances. So we have introduced few terms here, one is the **source of EMI**, then you have **the receptor or the victim** that is being disturbed and you have a

coupling path for electromagnetic energy between the source and receptor. This is called a decomposition of the EMC problem. You can have **radiated interference**, you can have **conducted interference** and you can have **emission** and you have **susceptibility** also. Now from these terms we can come to what do you mean by achieving EMC.

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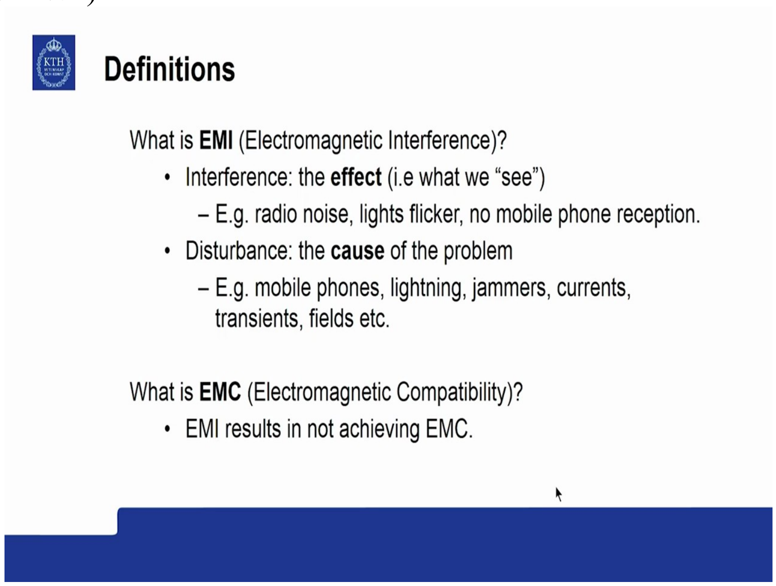

So what is EMI? It is interference effect that is what we see or what we experienced For example, radio noise, light flicker, no mobile phone reception due to some reasons. And what is disturbance? The cause of the problem. Say for example it can be mobile phone transmitters, lightning, jammers, currents in some circuits, transients, fields, et cetera.

And EMC is defined as an electromagnetic interference issue. And when you have an electromagnetic interference issue, you are not achieving electromagnetic compatibility between the source and receptor. So this is called EMC, electromagnetic compatibility. So we say that we achieved such kind of a state. So we achieve electromagnetic compatibility if there is no electromagnetic interference or we call it as electromagnetic interference only if it causes a problem. So if we do not have this problem between two systems, we say that okay we have achieved EMC.

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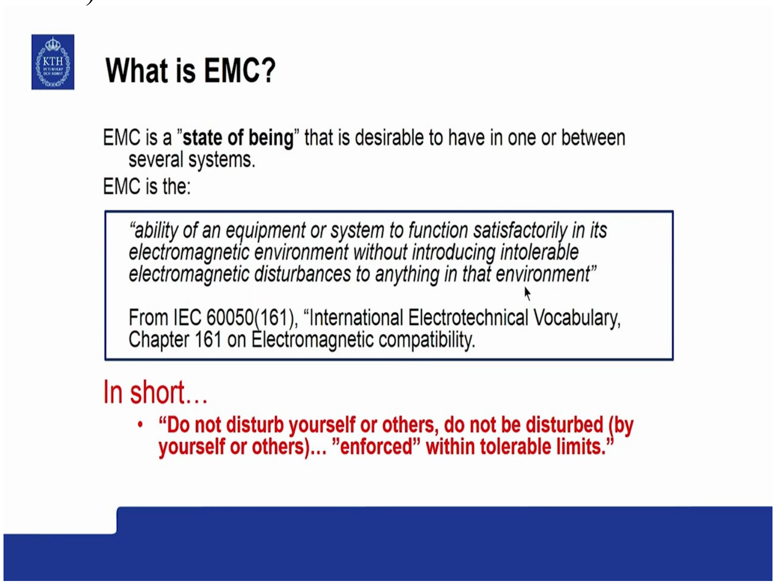

So EMC is a state of being that is desirable to have in one or between several systems. So we can have a formal definition for EMC. This definition is taken from International Electrotechnical Standard 60050, International Electrotechnical Vocabulary chapter 161 on electromagnetic compatibility. It states that ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

Any device will produce electromagnetic fields, currents and voltages and often it will not create any problem. Then we do not have any EMC issue. EMC issues comes only if it is creating a problem. And you have to think that you can have two perfectly harmoniously working systems. And say system A and system B. In system B at a later time, you are making some changes and you are introducing new electronics or something like that. Then suddenly you might find that okay system B is now susceptible from system A because the design of the system has changed and the previously existing electric and magnetic fields or currents and voltages are now becoming disturbing for system B.

So it does not mean that once you have achieved EMC, you are achieving it for all the time. Whenever you make some changes, you have to re-evaluate whether EMC is still being achieved. So it is a more dynamic thing. It is not anything static. Depending upon the operation condition of your equipment, your EMC status get changed also because under some operating conditions, you may produce certain kind of fields that may be more interfering.

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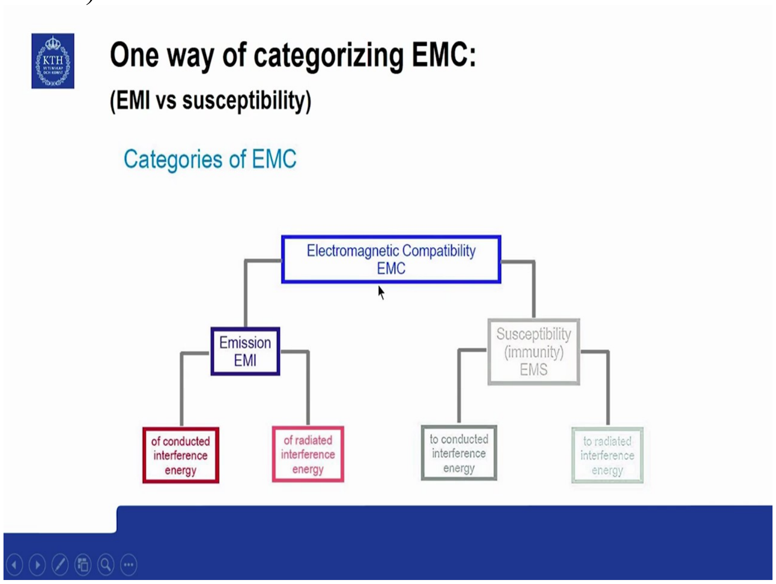

So there is another way of categorizing EMC in terms of electromagnetic interference, that is, emission from the source side versus susceptibility from the victim side. Say, there is an emission of conducted interference energy or radiated interference energy. This may disturb system or if you are designing a system in a very harsh environment, you can approach it from another way. So here you are trying to minimise emission to achieve EMC. So from the source side, you design circuit in such a way that emissions are minimum, both conducted and radiated.

Now if you are designing a system that goes into an environment where there is a lot of electromagnetic noise, you try to make the system less susceptible or increase immunity, you immune the system from conducted interference as well as radiated interference. So from both sides, you can approach EMC.

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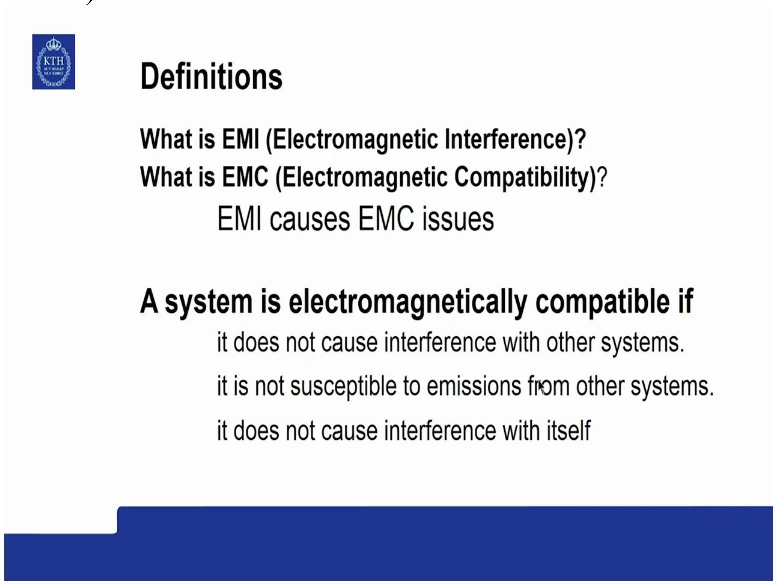

Now you have seen the definitions for EMI and you have seen what is meant by EMC and you have seen how EMI causes EMC issues. And formally, we can define a system is electromagnetically compatible if it does not cause interference with other systems. It is not susceptible to emissions from other systems and if it does not cause interference with itself. So often, this also is a problem because systems can have many various submodules, module 1, module 2, like that or subsystems and one subsystem can cause interference to the other subsystems.

Then this system as a whole may not work. So even this also has to be taken care of. There are these 3 aspects to the electromagnetic compatibility problem. It cannot cause interference with other systems, it should not be susceptible to interference from other systems and it should not cause interference with itself.

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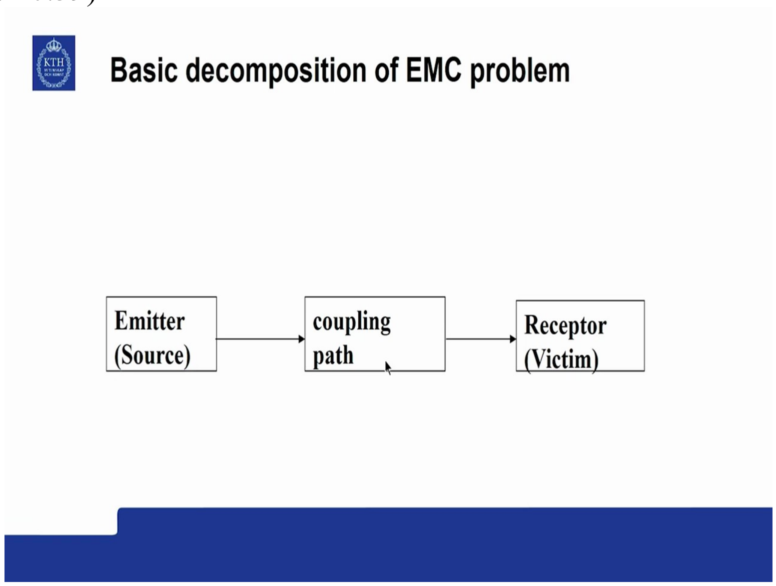

So in terms of basic decomposition of the EMC problem, we have seen the emitter and the victim and the coupling path. Now in later chapter when we go into the reasons for the EMC issues and how to solve the EMC problems, one basic presupposition is that you clearly know what your emitter is, the source of the problem and you have a clear understanding of where it is causing the problem, the victim and often, this is very difficult in a complex system. And also you have to know what are the coupling paths of the electromagnetic energy.

Is it conduction? Is it through radiation? If it is conduction, through which kind of wires or cables between the systems? Once you really understand the problem and all the pathways, then it is easier to design the solutions for it. So the ability to decompose the EMC problem into these three categories is very important and this is where most of the time will be spent by an EMC engineer.

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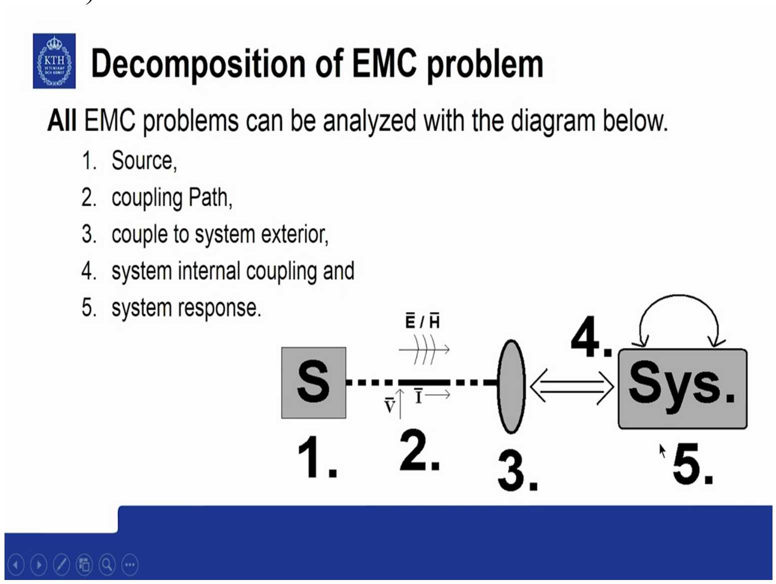

To decompose the problem with more details, for example, we have the source here, number 1 and the coupling path to the victim here. Numbers 3, 4, 5 are victim system and have an interior as well as an exterior. So coupling to the exterior and from there to the interior, system internal coupling, and through that, the system will respond, the system response. So it is the system response that will manifest as kind of interference. If you are able to decompose the problem like that, we know how to solve the problem also and in later chapter you will see theories of transmission line mainly to be able to analyse the conducted transient issues.

We will see theories of electromagnetic fields especially uniform plane waves and different types of Maxwell's equations - Faraday's law, Ampere's law, Gauss' law et cetera. That is, to understand how electric and magnetic field produced by a system is coupled with other systems, you have to do the mathematical calculation and mathematical modelling. And also you have to see how common materials behave in the presence of electric and magnetic fields - like metals. Conducting materials as well as non-conducting materials. These theory sections, we will deal with in chapter 2. So this is basically an introduction to the EMC problem.