Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
Professor name: Prof. Amitabha Bhattacharya
Department name: Electronics and Electrical Communication Engineering
Institute name: IIT Kharagpur
Week :10
Lecture 49: Shielding

 Welcome to the lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Application. We have seen conducted emission and conducted susceptibility problems in the last class. Today we will start a new topic that is shielding. Shielding means a metallic enclosure that completely encloses an electronic product digital device or a portion of that product. These are metals and you have a device here. So, that is radiating. So, this is also called a this metallic thing is called a shield and you have another product which could have received this emission, but you do not want that. So, it is preventing that this shield is preventing those emission by the product. So, this is this type of case is to contain internal emission of the internal I will say radiated emission of the product, this is your product. The shield serves another purpose. So, this is the shield and you have your product here and from outside a product is emitting, but there is nothing going here because of the shield. So, we can say to prevent external radiated emission to enter the product. Example, the best example is the anechoic chamber where a all measuring things are put inside a pure metallic room. So, that is the B type case. Now, the A type case is you see in all personal computers you have a metallic shield. So, that the products emissions because there are clocks nowadays clocks are going to the range of gigahertz. So, there will be several harmonics of that. So, they if they go outside they will create disturbance. So, there are shields for the metal. Now, in reality it is difficult to have a metallic shield because there need to have penetration for power, penetration for interconnects like in PC you see the back side even the front side in front side there are USB ports etcetera the power button. So, there are perforations in the shield at the back side you will see the fan needs to be cooled. So, there are perforations, there are various connections from monitor, from printers etcetera. So, for that holes are there USB drives, USB ports. So, for that all there are penetrations, but most of the things it prevents because SMPS which is a switching mode power supply which is inside that creates a lot of interference. So, all those are quite good amount significantly they are absorbed by the shield. Now, you see that printers they are not shielded. So, because it is very difficult to shield a printer you should have much openings the paper is coming out, paper is going in etcetera. So, that is why printers do not have a shield. So, shielding is not the solution every time, but in certain cases it gives you very good result.

With this introduction let me come to the concept of figure of merit of the shield which is called shielding effectiveness or in short we will call it AC. So, what is a shield? I have a metal shield, metal sheet let the thickness of the metal is T, this is of metal this is my x axis, this is my y axis, this is my z axis. So, this is at z is equal to 0 to z is equal to T. Now, the material parameters here is epsilon naught mu naught, here it is also epsilon naught mu naught and the incident field is E I, H I and it is E I, it is going in z direction. Similarly, in the outside some of that will come out and go here. So, our shield is in the x y plane I have drawn it, but actually it is in the x y plane and the wave is going in z direction. Now, with this diagram the AC is defined as 20 log E I phasor by E T phasor, this is the electric field incident electric field, this is the transmitted electric field that is why we have put 20. Generally, AC is expressed in dB scale and so you see E T is definitely less than E I that is why E I by E T the higher it is the shield is its effectiveness is higher. So, we want AC to be as high as possible. Now, how this incident wave is becoming this transmitted wave?

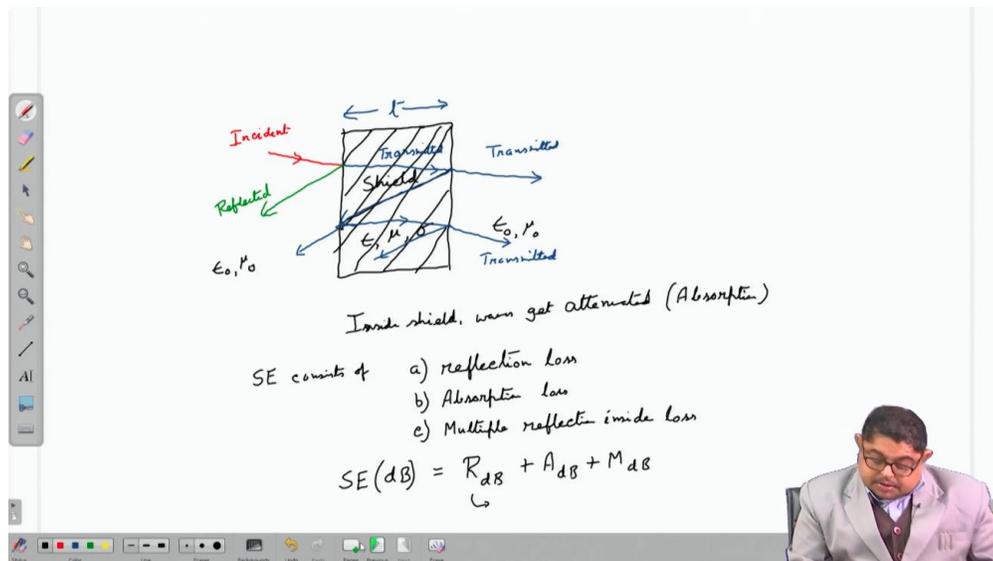Again, this is the incident wave. So, this is the sorry this is the shield, this is the shield thickness. Let us say this is my incident wave, I am not showing the electric field magnetic field, the wave direction k vector only I am showing. So, incident field is here, let me draw there will be from here a reflected field because it is a metal, but it is not a perfect metal. So, some transmission inside will be also there. So, from here some of the thing will be transmitted. So, I will say transmitted field. Now, here again it is showing a material discontinuity that I have not shown that here it is epsilon 0 mu 0, here it is epsilon mu, here it is again epsilon 0 mu 0 and here this is not free space. So, some conductivity will be there for perfect conductor, perfect metal it will be infinity conductivity, but in our case it is not. So, we have shown this. So, this transmitted wave after coming here it is showing a second interface because the material discontinuity is there material parameter discontinuity. So, some of it will come back, some of it will come back and some of it will flow here as a transmitted. This one again some portion will go from go out from here, some portion will be reflected, then from here again some portion will come here, some portion will get transmitted from here. So, this how the transmitted one is going. Now, this process will go on. So, you see that waves they get reflected. Now, some of the waves they enter into the shield, in the shield you see this is having an sigma. So, it will get attenuated inside. So, I can say that inside shield waves get attenuated that actually gives rise to a phenomena called absorption. Now, if the thickness of the shield T is much greater than skin depth of the shield material, then a very weak signal comes out at the second interface of the right end, but there multiple reflection that always go on in the shield. So, we can say from these that shielding effectiveness consist of a c, consist of a reflection loss because you see there is a reflection at the first interface. So, there is a these are the physics of the problem reflection loss B inside the shield there is an absorption loss and inside the shield absorption loss is when from one portion to other end it is going the wave gets attenuated because it has a conductivity also it has alpha. So, and, but this multiple reflections. So, due to that again here you see there is a reflection loss again here there is a reflection loss. So, this there is a phenomena called multiple reflection inside. So, actually these losses they are multiplicative reflection loss into absorption loss into multiple reflection inside I will say loss. So, we can say a c in dB will be sum of these three losses.So, we can say a c dB is equal to R dB plus a dB plus m dB.

Inside shield, waves get attenuated (Absorption)

SE consists of
a) reflection loss
b) Absorption loss
c) Multiple reflection inside loss

$$SE(dB) = R_{dB} + A_{dB} + M_{dB}$$

 where R is or let me write in the next page because these will be required later where R is reflection loss at first and second interface. Why I am saying that because you see the other ones they actually if the shield is good it has good conductivity etcetera then it after going to here the signal becomes comparatively weak and going inside and multiple reflection that we are taking the second reflection from here that means, this wave this one this one they are we are not considering only the first reflection we are considering as R dB. Then a is absorption loss of the wave as it proceeds through the barrier or shield through the shield and m. So, additional effects of multiple reflection and transmission in the multiple reflection and transmission inside the shield. So, now, rest will find some expression for this so that we can calculate the shielding effectiveness of one shield and compare various shields. So, we need to evaluate this R a and m in terms of the material parameters, but for sources there are two cases you see the source from where this wave is coming I have shown here arbitrarily, but that may be far away from the shield that means, the shield may be at the far field of the source incident or it may be at the near field because we do not know in small enclosures small p c b etcetera there may be the source of emission may be very nearby. So, these two are two different cases. So, we will first start with shielding water content shielding effectiveness for far field sources that means, from very far away if it is coming to the shield. So, now, if the source is far away we know that at the far field the incident waves they behave as uniform plain wave. So, we can express the fields as the uniform plain wave fields all of us know uniform fields. So, that we will use. So, we are assuming that we have a X directed E I. So, we will have a Y directed H I and a Z directed wave flow. H R is this and the wave is getting reflected. Similarly, here this is our E t this is our H t the wave is flowing in the positive Z direction. Now, inside you see that the when the wave hits here the just in the inside that

means, at Z is equal to 0 we have also a E 1 you can see this is at this point we will have a E 1 and that wave when it goes here will comes from here that we are calling E 2. So, with this we are also showing. So, this is E 1 this is H 1 and this is E 2. So, this will be having an E 2 will be having an both of them are inside. Now, you see that this E t is going now we are not assuming any reflected wave from the right side because we are assuming that there is no other shield or barrier or any obstacle in the right side the whole scenario of free space extends up to infinity. So, otherwise there will be reflected waves that will be complicated model the shield is in the x y direction x y plane. So, now, our job is to. So, E I let us say we know E I H I E I if I know E I H I is known because E I by eta naught is H I. So, E I is known our job is to find E t H t for this far field case not H t even E t will do and then we will be able to find shielding effectiveness. So, that is our job. So, in the next class we will start doing that. Thank you.

where $R \rightarrow$ reflection loss at 1st and 2nd interface

$A \rightarrow$ absorption loss of the wave as it proceeds through the interior shield

$M \rightarrow$ additional effects of multiple reflection and transmission inside the shield

Shielding Effectiveness for farfield sources