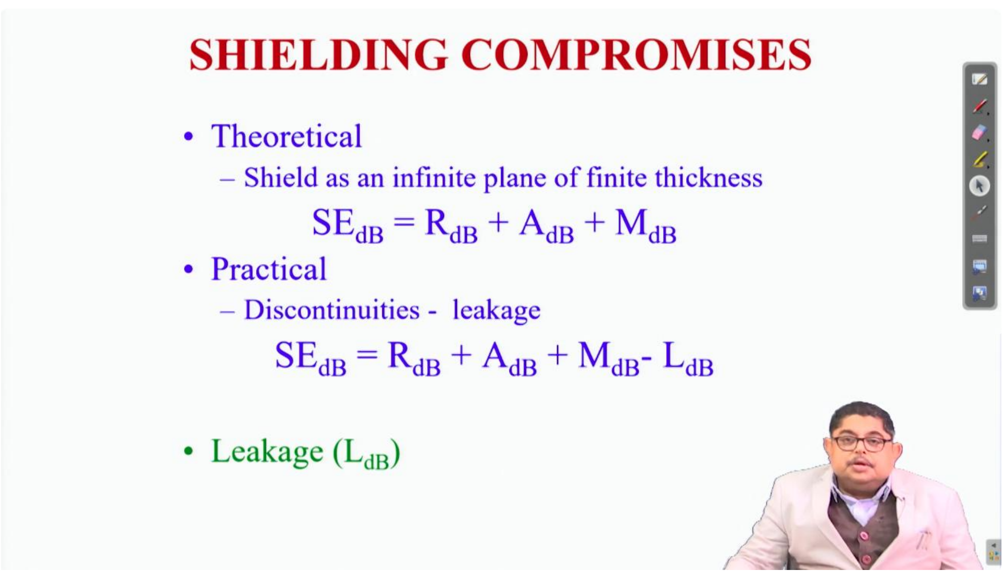
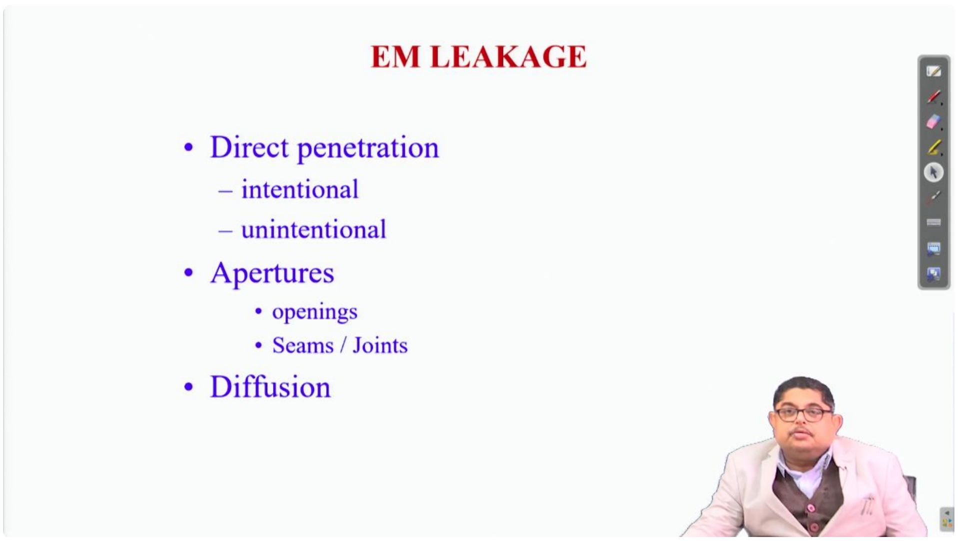
Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
Professor name: Prof. Amitabha Bhattacharya
Department name: Electronics and Electrical Communication Engineering
Institute name: IIT Kharagpur
Week :11
Lecture 54: EMC System Aspect for Shielding

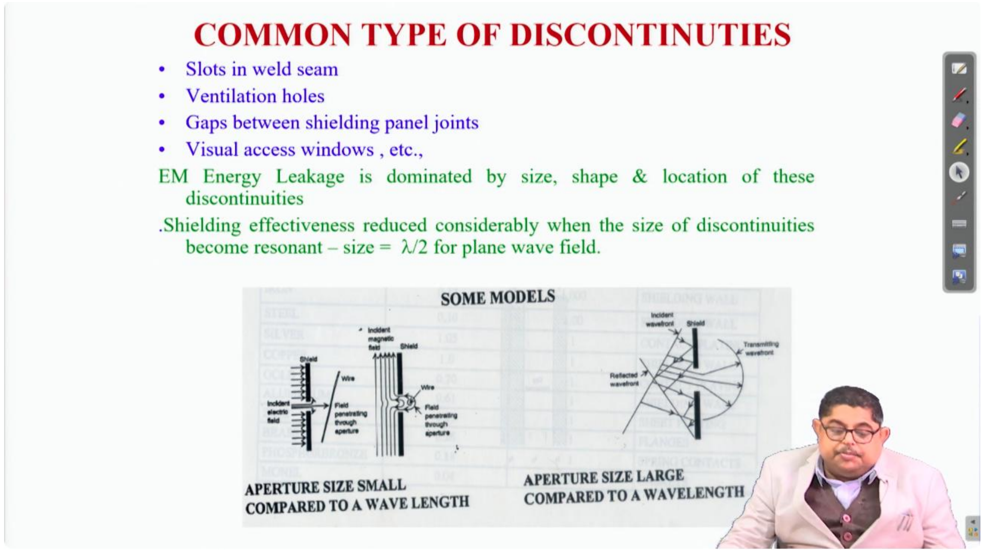
Welcome to the lecture of the course on EMI-EMC and Signal Integrity Principles, Techniques and Applications. Now, we will see from the system aspects, EMC system aspects for shielding. So, as a system when you consider there are various subsystems in a system. So, in that how you enforce EMC. So, you see that theoretically we have considered that shield is an infinite plane that means, in the x y plane it is infinite with a finite thickness in the z direction that we have considered, but actually it is not infinite. So, there will be some discontinuities, some leakages those are deliberately made to insert on the shield. So, that you can put your cables, you can put your various heating holes etcetera on it. So, discontinuities they give some leakages. So, in shielding effectiveness that also we should consider. So, that will decrease the shielding effectiveness. So, that is called leakage. So, that is we are designating by L.



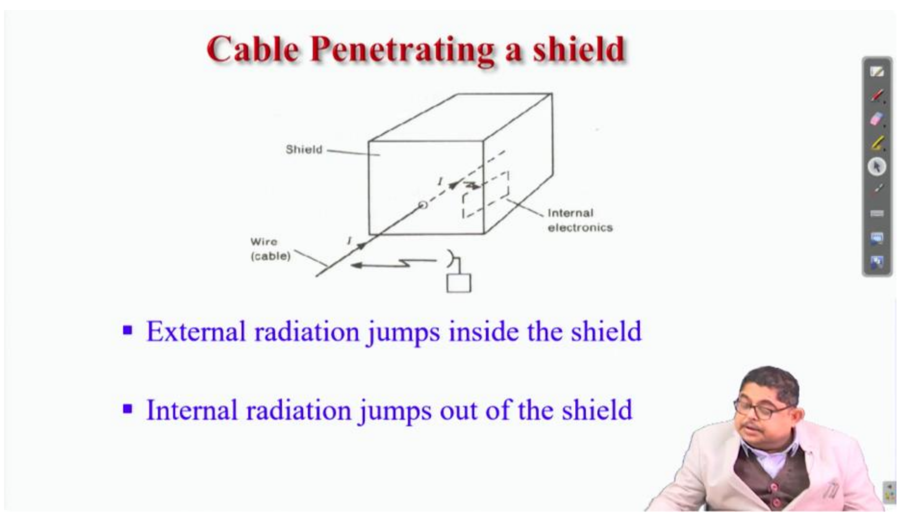
Now, EM electromagnetic leakage. So, there will be some cases are direct penetration. So, with the wires etcetera connecting wires, power supply wires some intentional sorry unintentional penetration goes also in some cases intentional radiation is also intentional penetration is also we put because if you do not put power supply how will you get the inside device to work. So, that is an intentional case. Now, in that path some outside EM fields will also go that is an unintentional path. Similarly, there will be apertures for various openings you will have to have some cooling things etcetera. So, seams, joints etcetera will be there and whenever they are there they have certain gaps. So, through that the electromagnetic field will diffuse. So, these are the leakage they contribute to the leakage.



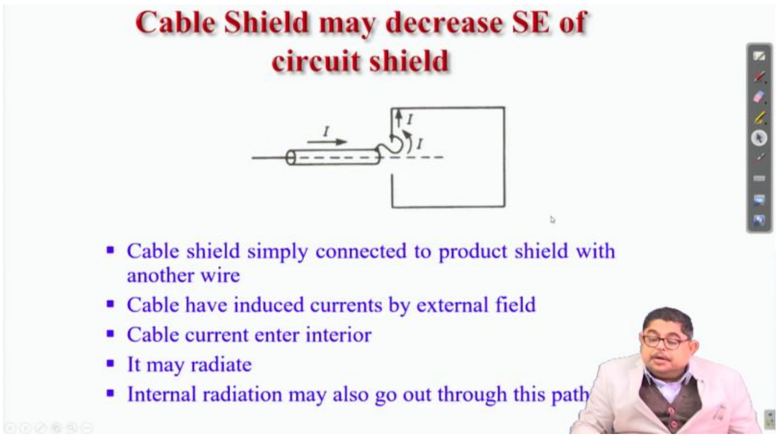
Now, common type of discontinuities slots in weld seam, ventilation holes as I was seeing, gaps between shielding panel joints because two panel if you join there will be definitely some gaps. Then visual access windows you want to see inside what is happening like in a microwave oven you see it is well shielded, but in front there is a visual opening window. So, you want to see from there etcetera. EM energy leakage is dominated by size, shape and location of these discontinuities. Now, shielding effectiveness reduce considerably when the size of these discontinuities become resonant size that means, lambda by 2 for clay monomer fields. So, you see this is the case where aperture size small compared to a wavelength whereas, so here in the left picture the there is not much leakage, but aperture size large compared to a wavelength. So, you see there is a large amount of leakage. So, these are modeled like this.



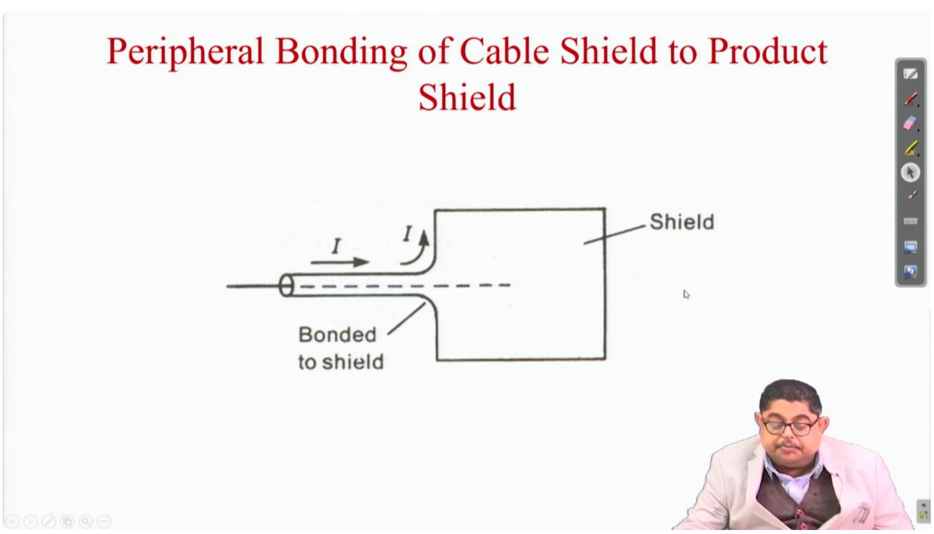
Now, let us see a cable penetrating a shield, this is a required cable now that is the internal electronics to which it is going. So, this is the path for that taking that wire, but also there is a nearby radiator. So, he is radiating some radiated emission, so this it is unintended, but that is also using this path and going inside. So, we can say external radiation jumps inside the shield. Similarly, for this internal electronics also through this path they also can come and jumps out of the shield.



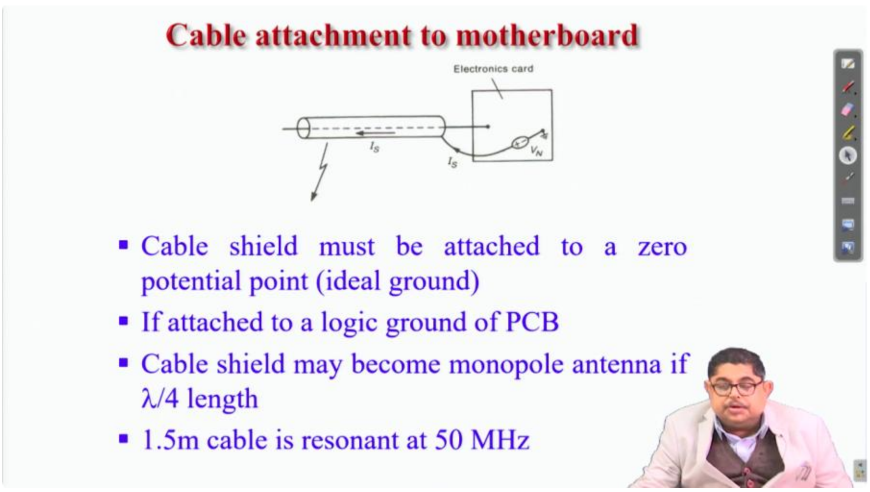
Cable shield may decrease a c of circuit shield, circuit means which is our actually electronic circuit inside. Now, you see that suppose this cable is simply connected to product shield with another wire that means, to the circuit shield it is if it is connected like this. So, cable have induce current by external field cable current enter interior it may radiate internal radiation also may go out through this field.



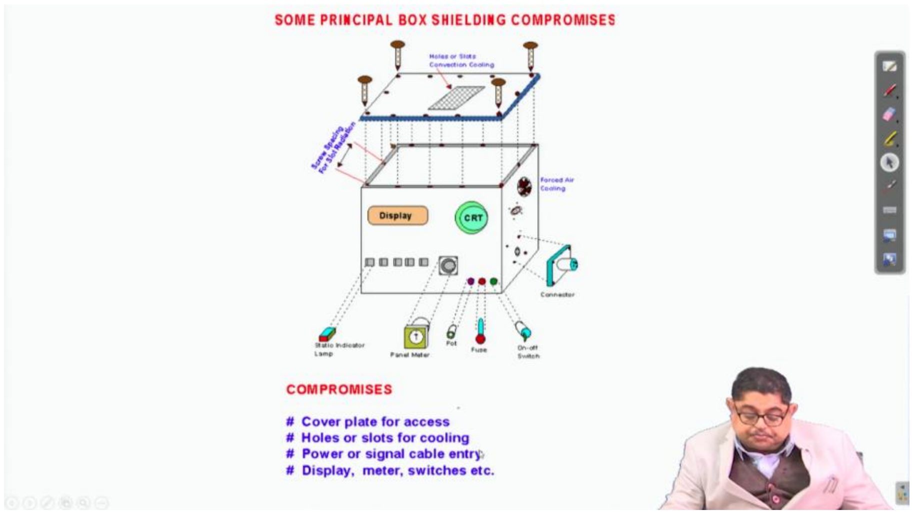
So, but instead of that connection if you go like this then the current cannot go inside. So, this is called bonding so you have a shield, so at the design level if you give if you pay attention to EMC problems instead of connecting that lose wire you will connect it make the bonding like this. So, this is bonded to the shield that is why the term bonding is coming .



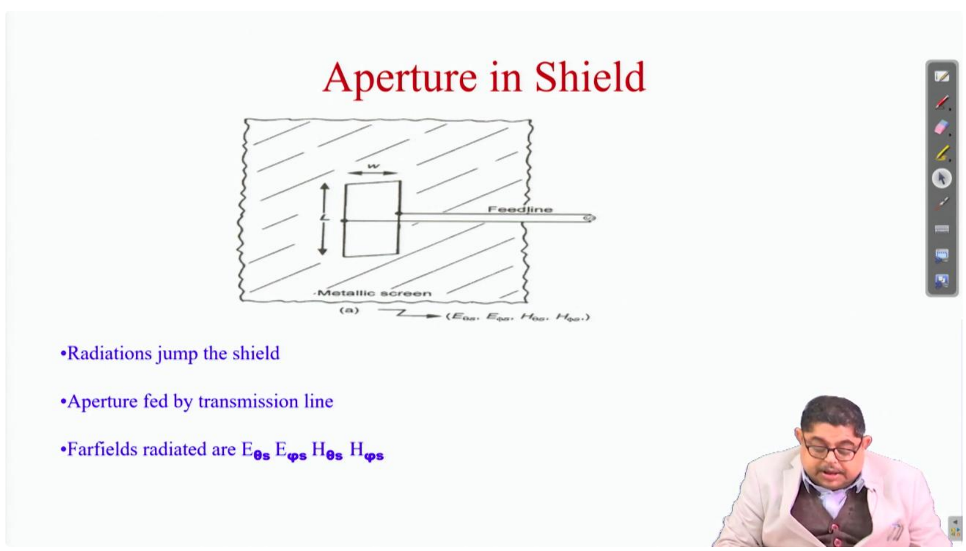
cable attachment to mother board here also that electronic card is there this is there you are now this whatever you are connecting that is again will radiate. So, if it is connected to real ground that is a 0 potential point then it would not radiate, but many times the electronic card is connected and shield is attached to a logic ground of the p c b. Now, logic ground is not always the real ground, so that may become monopole antenna if lambda by 4 if it is of lambda by 4 length because then it gives like a monopole and it gives lot of radiation. So, shielding effectiveness decreases 1.5 meter cable is resonant at 50 megahertz. So, if you have a 1.5 meter cable at 50 megahertz you may get a EMC and EMI. So, you should be aware of all these things.



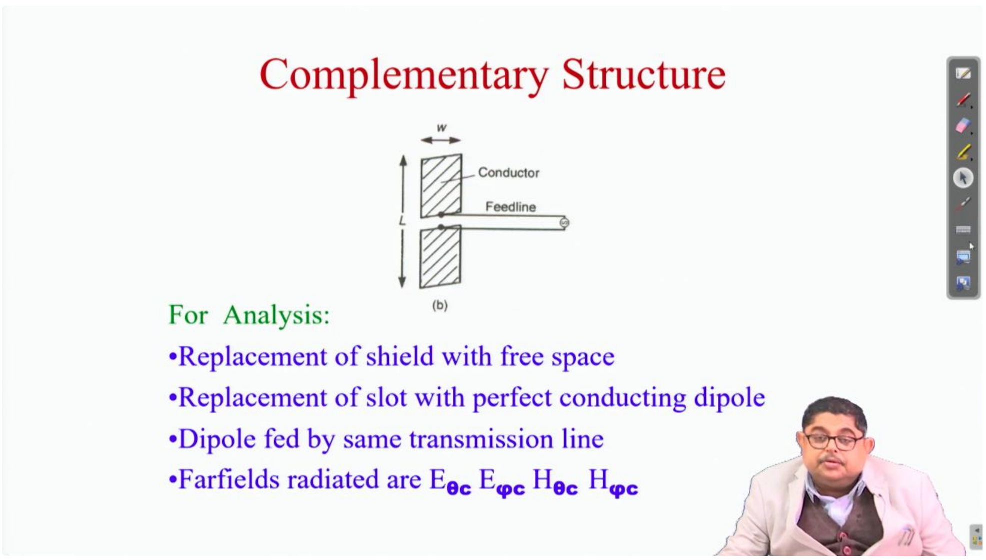
some principle box shielding compromise you see as a box shielding you at the top there is a for make for cooling there is an aperture then screw spacing for slot radiation. So, you see that from here it behaves as a slot in a wave guide. So, from here radiation matrix for display you have a some aperture for some wave guide. So, CRT terminal you have some aperture you have static indicator lamp all these lamps require some aperture. So, panel meter here is an aperture if you have a pot there is a hole if you have a fuse there is a hole on off switch there is a hole then for connectors you are connecting. So, here are some of the holes coming into play forced air cooling sometime some phone fan that is placed. So, that gives a lot of a large hole. So, display meter switches etcetera this you can self evident you can understand.



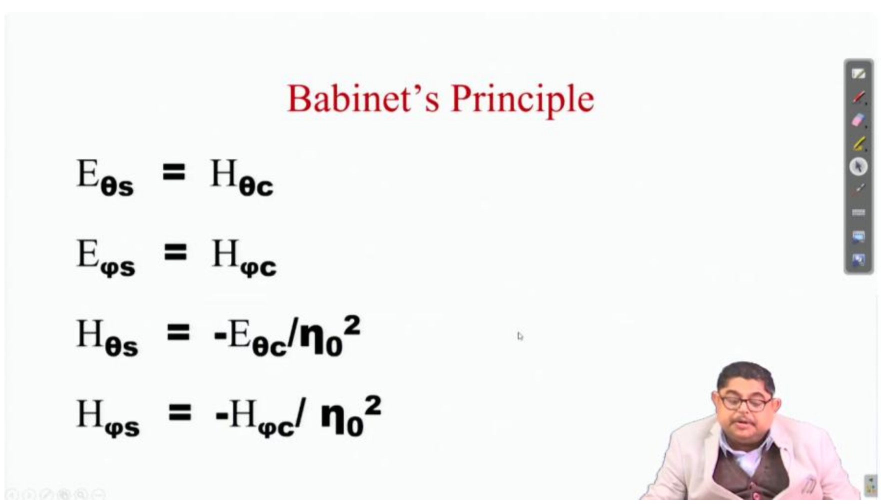
So, that means largely there are two types of things one is aperture in shield another is holes in the shield aperture is fed by a transmission line. So, there will be far fields e theta e phi h theta h phi this components will come out s in the subscript is for shields.



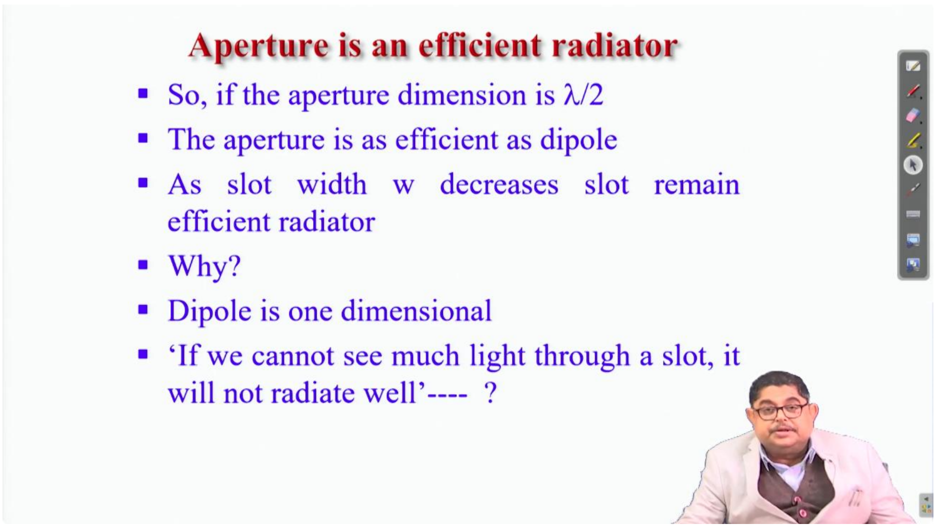
Now for analysis it can be shown. So, this is the field which is the field which is the for analysis you can use duality the shield you see the shield. That means, this hole what is that the checkered one that can be replaced with free space that is the duality and then replacement of slot with perfect conducting dipole. So, you see now the aperture which was just a without any material thing in duality it will be filled with perfect conducting material. So, it becomes a dipole sort of thing. So, here also you can see that also far field radiated will be e theta e phi h theta h phi the c subscript is coming for this is a complementary structure .



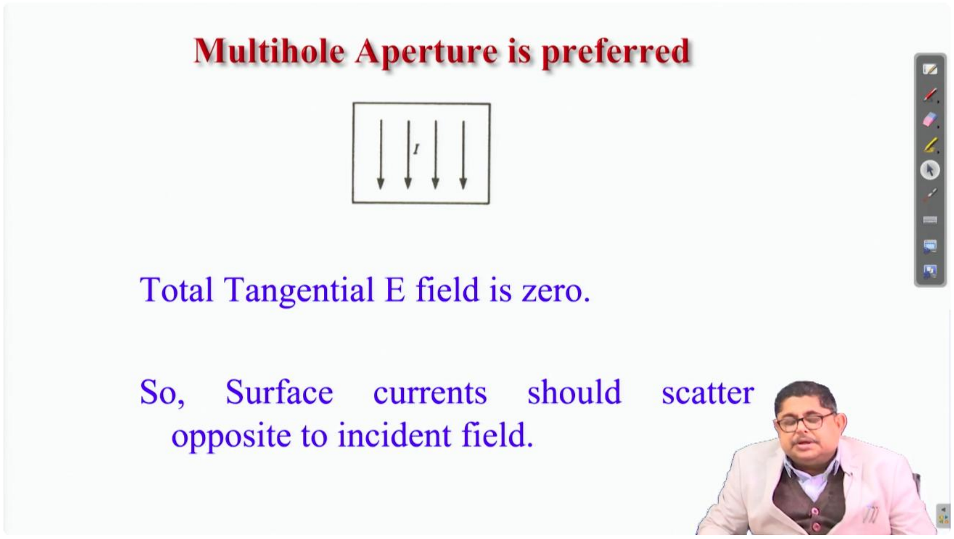
who gives this complementary structure in babineets principle from duality it can be shown that e theta s is nothing, but h theta c e phi s is h phi c h theta s is minus e theta c by eta naught square h phi s is minus h phi c by eta naught square.



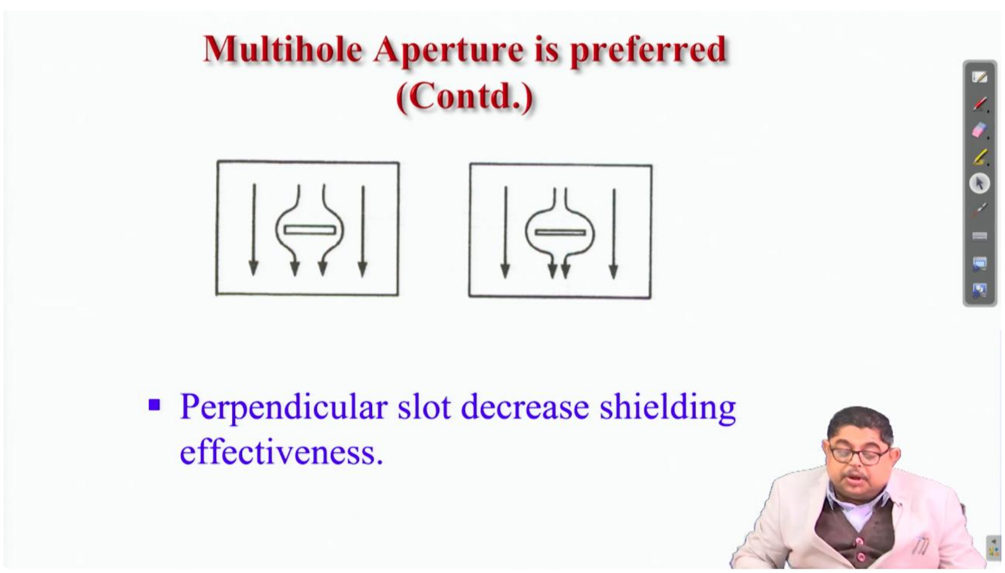
So, that means, aperture it can be analyzed, but simply we can understand that for analysis purpose it is nothing, but a dipole. So, if its dimension is lambda by 2 the aperture is just like a del lambda by 2 resonant dipole as slot width decreases still slot remains efficient radiated because it is a dipole is a one dimensional concept. So, even if you decrease the slot width that means, the apertures width nothing will happen the radiation is still taking place that is why put a y that explain in that it is a one dimensional. If we cannot see much light through a slot it will not radiate well that is obvious that in a slot it will not radiate well. Because, light is also electromagnetic energy. So, from somewhere the light is going and then if we cannot see means sufficient light is not coming that means, electromagnetic radiation also will not take place for that you will have to see through it and the in the actual system you will have to see. So, if you see that sufficient inside things are visible then you apply your EMC concept that how to fix that problem.



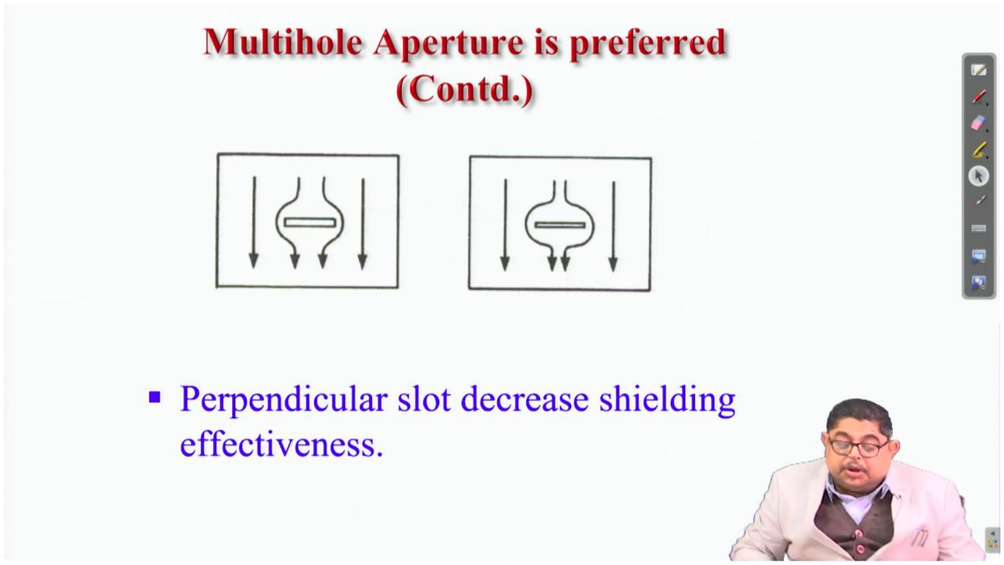
Then in an aperture you will see sometimes multiple holes are there why that we will explain you will see if you open the see the back side of any computer shield there are some apertures which are hold. So, why that is there? So, to understand that consider these that in the aperture there are the currents created how it will be created I cannot say, but those of you who have done masters class they know that we call something like magnetic current. So, that magnetic current close to the aperture. So, total tangential field should be 0. So, surface current should scatter opposite to incident field then only the total electric field tangential electric field can be 0.



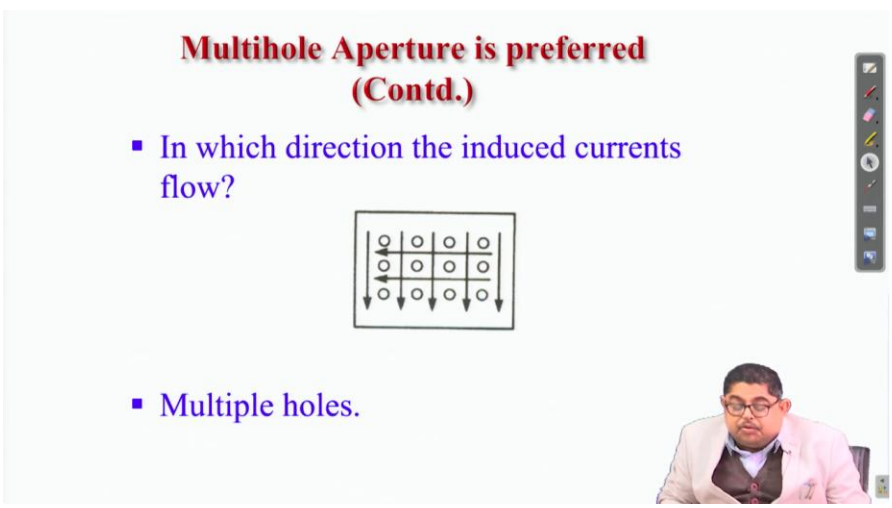
Now, in that suppose you have put a hole here I am showing the hole as a rectangular hole or a slot. So, if you do that you see you are concentrating the currents the magnetic current if they concentrate then there will be more radiation that means, the transmitted field will increase. So, shielding effectiveness decrease.



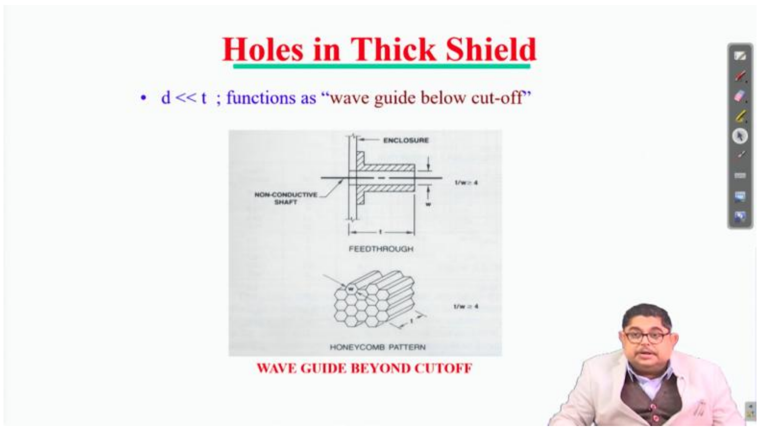
But if you do it like this that means, parallel slot or parallel hole if you put then it does not affect you see because you are not changing the induced surface current.



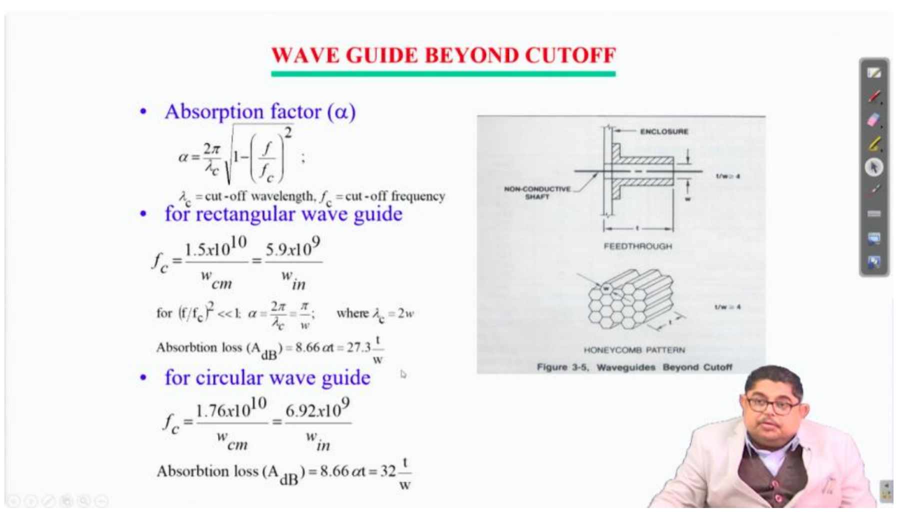
Now, if you do the holes like this then you see in all the directions the currents are flowing, but they are not affecting the signal entity. So, this is a way by mitigating the aperture problem. So, multiple holes are cut to have this type of picture where due to that multiple holes there are no distortion in the magnetic field.



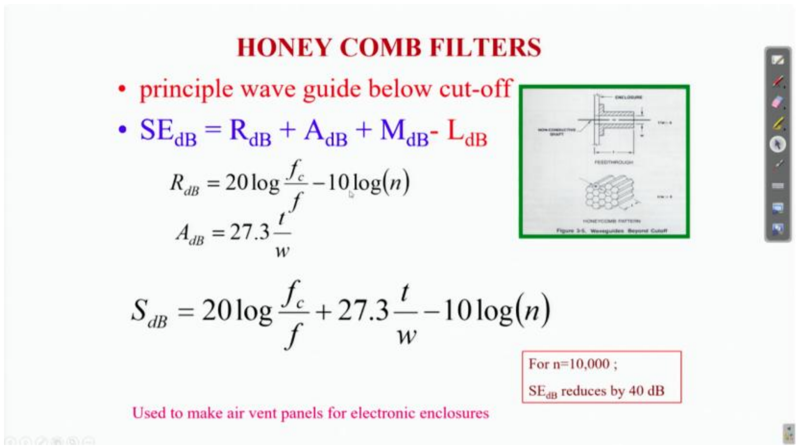
Also holes in thick shield they acts as wave guide below cut off. Now, you know cut off is a wave guide is a high frequent high pass circuit. So, below cut off it does not pass any radiation or any EM signal whereas, after cut off it passes. So, you can fix suppose you are working at 100 mega hertz. So, you can take the hole dimension in such a way that you it will be in the cut off region in that case that holes will not create any problem. Now, doing that on the full aperture may be difficult, but if you cut holes then apart from the advantage I said before they will be also behaving like a thing. So, that is exploited in this pattern called honeycomb pattern. So, here the holes are such that the dimension is such that they are in the cut off region.



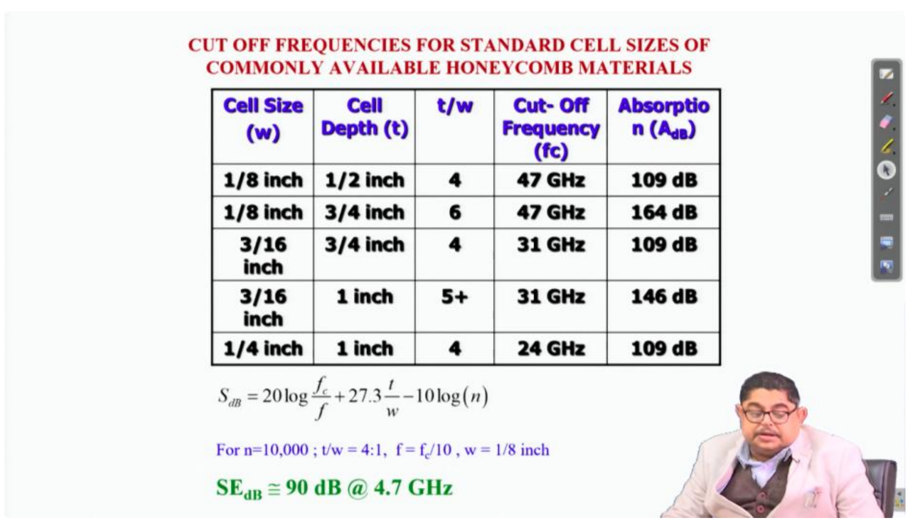
So, wave guide in the cut off region has this factor its alpha is this then for rectangular wave guide this is the formula whereas, for circular wave guide because many holes practical holes are circular. So, you will have this calculations. So, absorption loss becomes in this case 32 t by w in the rectangular holes they will be 27.3 t by w. So, this is the honeycomb pattern it is this type of pattern on the top which is being shown that is feed through pattern.



So, these are called sometimes CMC engineers call this honeycomb filters, but they are actually aperture with holes or multi hole apertures. So, here if you have how to calculate the L here to see that the RDB and ADB terms you know ADB is this, but this is the temperature if you have n number of holes then your decrease in the a CDB will be if it is L that L will come by this term is minus 10 log n. So, that is substantial as it was shown that if you have in a system 10,000 holes now 10,000 is a real system figure. So, there it reduces the shielding effectiveness by 40 dB, but even if you have in computers etcetera you see roughly 10 or 15 holes. So, that is not also very insignificant with the levels that is being talked of here. So, it is quite useful.

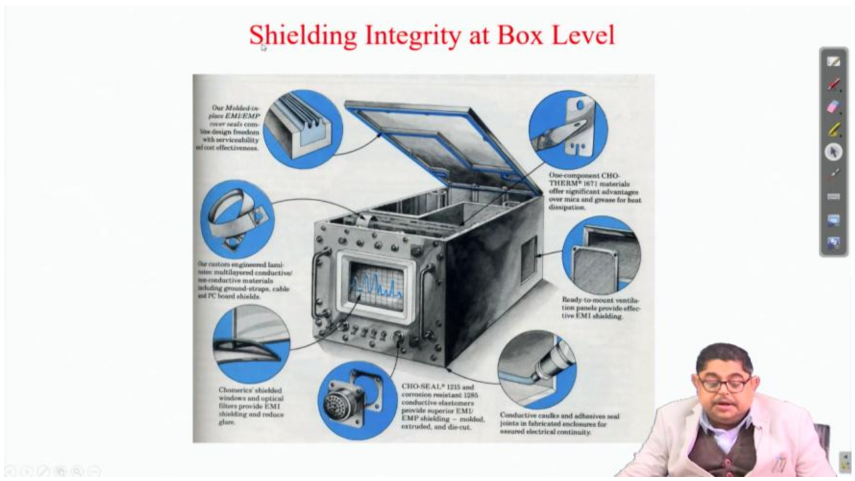


then cut off frequencies for standard cell sizes of commonly available honeycomb materials you can see various t by w ratio etcetera.So, absorption is for this is cut off frequency this is absorption. So, SDB is this. So, at 4.7 gigahertz they found that at 4.7 gigahertz that is the temperature shielding effectiveness becomes almost 90 dB. So, that is a good number.



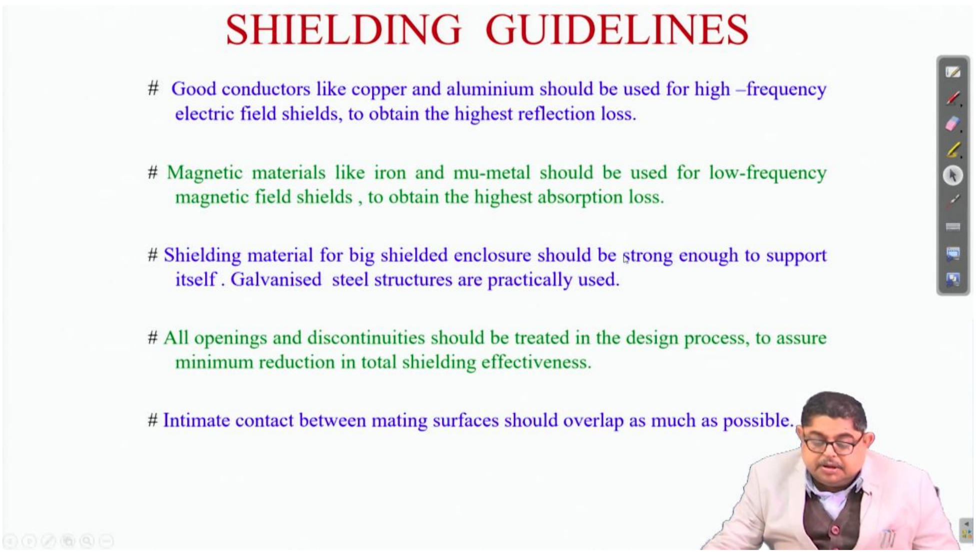
Cell Size (w)	Cell Depth (t)	t/w	Cut- Off Frequency (fc)	Absorption (A_{dB})
1/8 inch	1/2 inch	4	47 GHz	109 dB
1/8 inch	3/4 inch	6	47 GHz	164 dB
3/16 inch	3/4 inch	4	31 GHz	109 dB
3/16 inch	1 inch	5+	31 GHz	146 dB
1/4 inch	1 inch	4	24 GHz	109 dB

So, shielding integrity at box level you see this is the box. So, there are various shielding mechanisms ground straps this is an example of a strap these are seals MIMs. So, these are seals copper seals these are shielded windows these are that seal chow seal this is shielding this is the holes at adhesives joints ventilation panel. You see all are having aperture with multiple holes.



So, at the rack level you know that the cards etcetera there are lot of electronics is there with modern cards and there are very in a short space they are placed. So, there are lot of E M G issues. So, various E M C preventing components are used there some of them have been shown here this is from industry people who work for these shielding things from them this craft is available, but I do not have the exact source. So, I am not writing it here, but I am writing it I am acknowledging that these are all is the from industry.

Now, let us conclude with some shielding guidelines at the system level. So, good conductors like copper and ammonium should be used for high frequency electric source shields to obtain the highest reflection loss. Magnetic materials like iron and mu metal should be used for low frequency magnetic fields shields to obtain the highest absorption loss. Shielding material for big shielded enclosure should be strong enough to support itself galvanized steel structures are practically used. All openings and discontinuity should be treated in the design process not it is said that you should remove them because it is not possible actually these compromises you will have to make, but at the design time you should oversee or you should imagine what will be the those discontinuities accordingly you can E M C engineer can see that how to solve that. Intimate contact make always intimate contact between mating surfaces and so that the overlap as much as possible.



also I think there should be clean that surfaces to be mated must be clean and free from non conducting finishes. Materials to be selected not only from shielding view point, but from electrochemical corrosion view point as well. So, as an E M C engineer again you will have to teach the designers etcetera that how to think like this that not only E M C there are also other issues, but E M C is definitely one of the big issues. Now after that it is the system integrator will decide whether you will listen to you or to others, but your job is to point out. So, that this is wrong or this may create problem later etcetera. Cable shields are to be peripherally bonded to connector back shells to maintain shielding integrity as I showed that cables should be bonded. Now if you do not conceive that at the design level it is difficult to have bonding at a later time. Enclosure opening may be shielded with finger stalks, conductive brush skates, honeycomb vanes etcetera considering cost factors and seriousness of aperture leakage.Shielding must be grounded shield must be grounded shield must be grounded for electric field and plane wave field incident for edge field grounding may or may not be essential from E M I point of view, but essential for safety purposes. I think with this we can end our discussion on shielding in the next class we will see some other aspects which are still remaining. So, mainly our theoretical all discussions are over we will see some other things as a that means we will increase your width of E M I E M C basically E M C actually the depth is over and the angle of the beam is also over the width is remaining. So, in the next 5 classes we will cover that. Thank you.

SHIELDING GUIDELINES (Contd.)

Surfaces to be mated must be clean and free from non-conducting finishes.

Materials to be selected not only from shielding viewpoint, but from electrochemical corrosion viewpoint as well.

Cable shields are to be peripherally bonded to connector back shells to maintain shielding integrity.

Enclosure opening may be shielded with finger-stocks , conductive gaskets, honey-comb vents etc., Considering cost factors and seriousness of aperture leakage.

Shielding must be grounded for electric field and plane wave field incident. For H-Field , grounding may or may not be essential from EMI point of view but essential for safety purposes.