Electromagnetic compatibility
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Solution to EMC Problems

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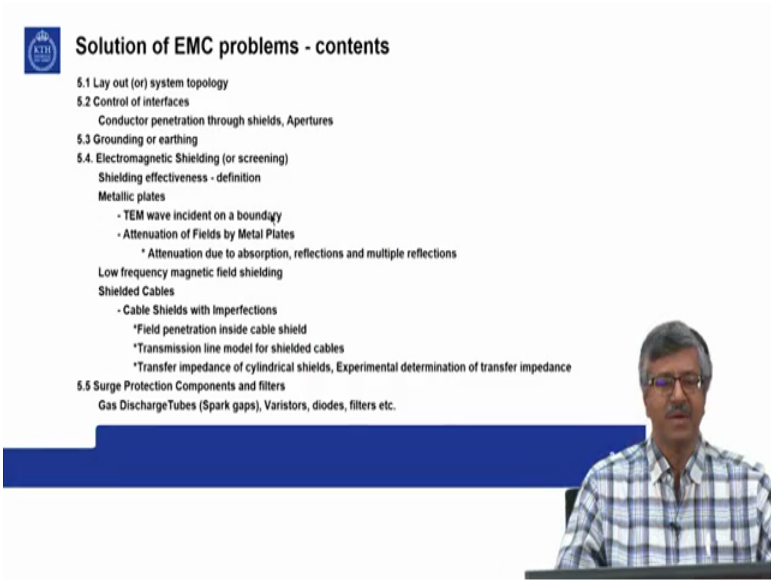

In this chapter we will look into the solutions to EMC problems. This is the content of the chapter, first we will look into layout or system topology, then after that control of interfaces especially concentrating on what we will do when a shielded enclosure has to be penetrated by different type of conductors and how we will deal with apertures or openings in the shield, then we will go to principles of grounding or earthing different types of ground.

After that the electromagnetic shielding the theory for that will be developed based on what we have learned regarding the electromagnetic principles in chapter 2. We will introduce shielding effectiveness, we will be concentrating on metallic plates especially a swimming a transvers electromagnetic wave incident on a boundary and this assumption is usually okay and we will consider also when the shields are in the near field.

And while describing shielding effectiveness we will decompose that into three parts attenuation due to absorption, attenuation due to reflection, and the phenomena of multiple reflection in the shield and discussion of this will also give us certain insight into the strategies for shielding against electromagnetic fields, brief mention about low frequency magnetic shielding will be done because often it is the magnetic fields that are more difficult to shied then electric fields.

The principles of shielded cables you have seen in chapter 4, but in this chapter we will look at shielded cables with imperfections because you have either brighter shields or solid shields and both has (cross shield penetrations) field penetrations and we will look at how to model this, the transfer impedance of cylindrical shields will be introduced and a method for experimental determination of transfer impedance will be described.

Then finally this chapter ends with surge protector components and filters, only some of the surge protection components will be handled the most common gas discharge tubes and varistors.

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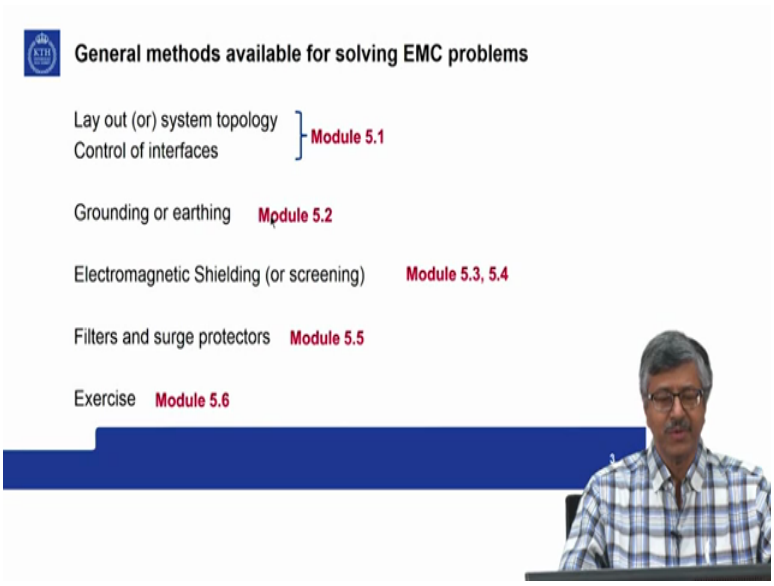

So the chapter is divided into six modules the last module is exercises.

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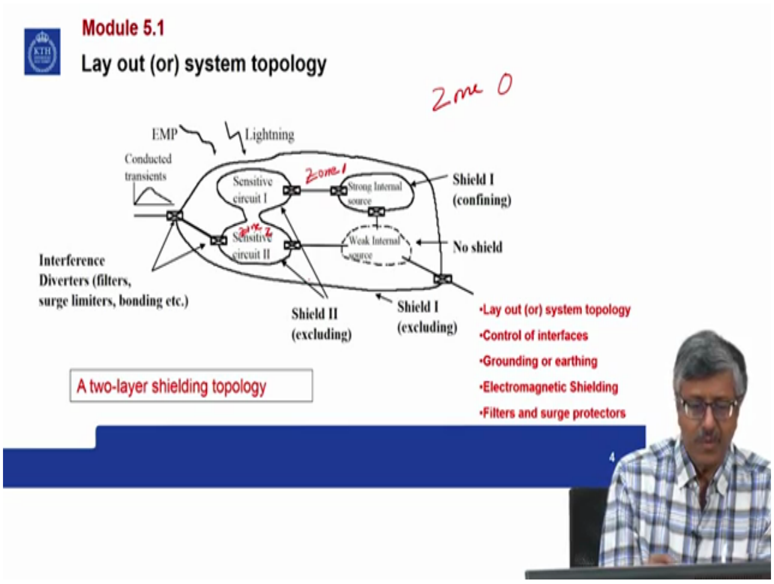

Now we take module 1, layout or system topology. Now assume that you have a area where you want to protect the system inside you want to protect from external electric and magnetic fields, so this is the area boundary. It can be an airplane or it can be a shielded enclosure or it can be a just a room where you have some sensitive equipments. So outside you have several harsh electromagnetic environment both conducted transients and radiated transients can get into this area.

Now how we use the system topological approach? What this means is that depending upon the strength of A field, B field and other currents you divide your volt space into different areas. Say for example this area outside of this you can say that it is one zone let say it is zone 0 or something like that and this will be very harsh enrolment and this zone over here it will be let us say zone 1. By the time the fields and currents reaches this zone you want to reduce it in value, then after that where the sensitive circuits are there this will be resolved.

So likewise you can consider it, so here this is a boundary so this boundary can be protected by a shield or some other kind of a structure so shield 1 can be excluding shield can be in the form of mesh or it can be you know like plates metal plates or something like that depending upon the cost and the purpose. Then after that you have another shield shield 2, so these two shields are for excluding the harsh environment, so here it will be let us say zone 2, so by the time it comes to sensitive circuits it would have reduced to very low value.

So this is called layout using system topology, but inside the system itself you have strong internal sources that can also produce disturbances because these disturbances can interfere with its own sensitive circuit part. So that you have to enclose into another shield that is again confining, so here the purpose is that you do not want to give out the fields or strong currents and voltages from this into the other sensitive system.

So you mark all these boundaries and you can control these boundaries by interference diverters like filters, surge limiters and bonding the details of which we will see later. Now there may be weak internal source that may not disturb anything else, so perhaps you may not have to do too much actions around it. So this type of layout is called topological shielding, so this is widely used in EMC, so this is the first defence in achieving EMC. So this you can see in the lightning protection also the same kind of principles.

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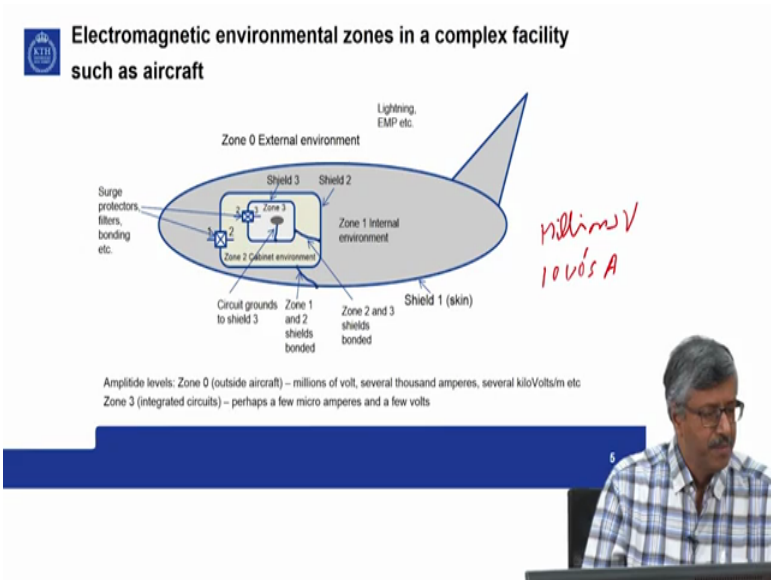

Now the above concept is described more carefully in this picture, so this is picture of an aircraft, here you have zone 0 external environment lightning, EMP, EMP is from (())(9:02) portion electromagnetic pulse that is zone 0 and zone 1 is internal environment, then you have a shield 2 again excluding kind of a shield, then you have shield 3 and here you have very sensitive flight control (())(9:27) things.

And the penetration from one zone to the other are controlled by surge protectors, filters, bonding, etc. Now if an aircraft on flight struck by lightning you know that the electric and magnetic fields can be of the order of million volts so it is of the order of several millions with respect to earth and thousands of amperes. Now this is reduced to very low value when it comes over here but at the same time you do not want to have very strong potential differences between any points inside this. So the bonding plays a crucial role, so when a plane is struck by lightning the passengers sitting inside what will be their potential with respect to the earth?

They are also at millions of volt because it is not the absolute value of voltage that is important it is the voltage differences that creates the problem. So you have seen people working on high voltage lines actually touching the lines and working as long as they are completely on a insulated platform because then they are at the same potential as the line, it can be 400 Kb or something, cross can sit on a high voltage line as long as it does not spread its wings and connect to the ground.

So the same principle is valid here also, so you want to make sure that there are no potential difference between the zone boundaries, so you connect all the grounds together bonding it together so this is extremely important in the protection. So this illustrate this layered zoning approach in achieving EMC. So this is the first defence against electromagnetic interference.

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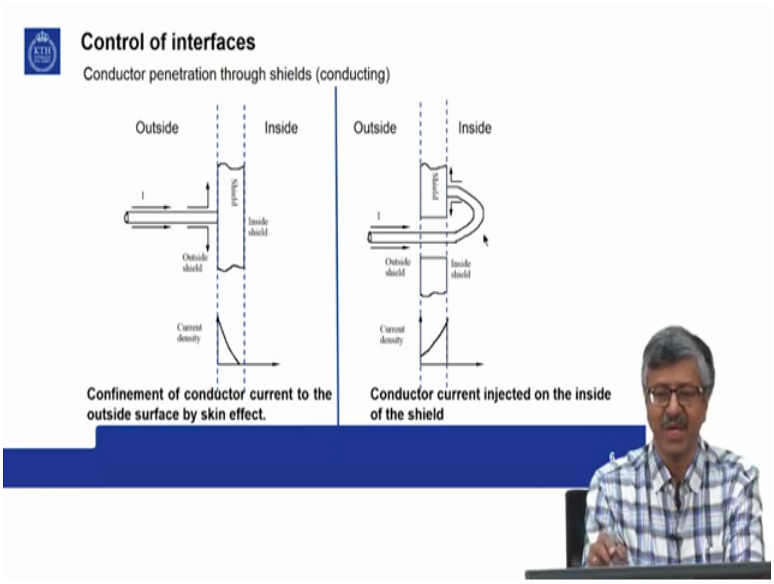

Now how do we control the interfaces? Because you can create different zones, you can bond the boundaries of the zones together if they are metallic, but often you want to have conductors penetrating it. So it can be grounding conductors, it can be insulated conductors, it can be water pipes, heating pipes, gas, communication cables, so how do we control that? So as much as possible you want to keep the zone boundaries separate.

So to understand that consider this case a conductor penetration through shields, so this is a metal plate we have seen in first chapter that when the current is terminating on the metal plate it confines maximum current will be on the surface if it is an AC current and depending upon the frequency more and more current will crowd to the surface and very less will penetrate to the inside.

So if the shield is thick enough you do not have any penetration at all through diffusion across the shield. So but if you have a hole and you are taking it through the hole so this is the outside of the shield and this is the inside, so this is one zone and this is another zone. So now you are violating the zoning principle because you are taking a conductor inside and connecting it here so all the currents can come inside the zone boundary and radiate further from.

And if you see the current density maximum current density or noise current is inside and it will radiate further. So you are completely destroying the zoning by having this conductor coming inside, so this need to be avoided.

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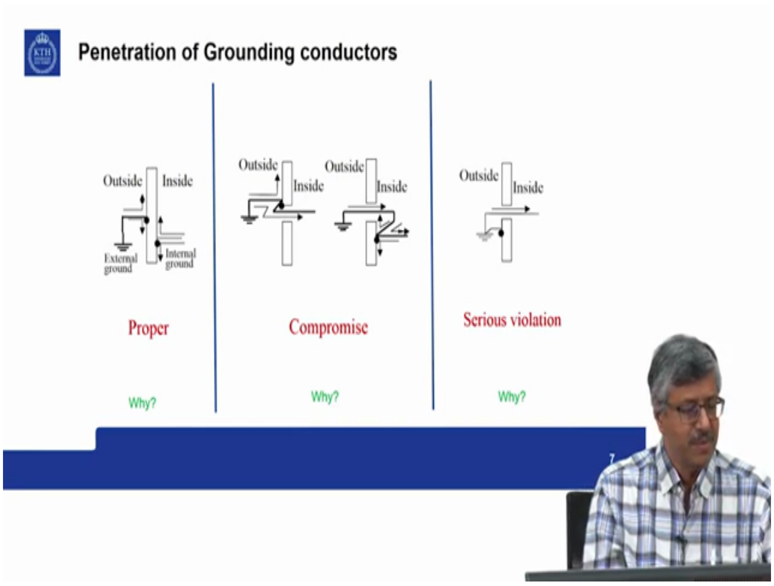

So what would be the best way of connecting grounding conductors? Now on the left side it shows the most proper connection, so if this is outside and this is inside and this is a boundary then internal grounds (())(14:29) on the internal part of the sheet, external ground (())(14:37) on the external part so in this way you can connect then all the noise coming from the internal part will be confined to inside, noise coming from outside is confined to the outside so you do not have any communications.

So this is a serious violation what you see on the right side this you should not allow because now you do not have any zone separation between outside and inside all currents are coming inside all the noise currents. Now this is kind of a compromise this is not the best situation but if this type of connection is not possible one can do something like this. So you can try to explain why it is so the most proper and why it is serious violation and why it may be a compromise by looking at where the currents will be and looking at the zoning principles.

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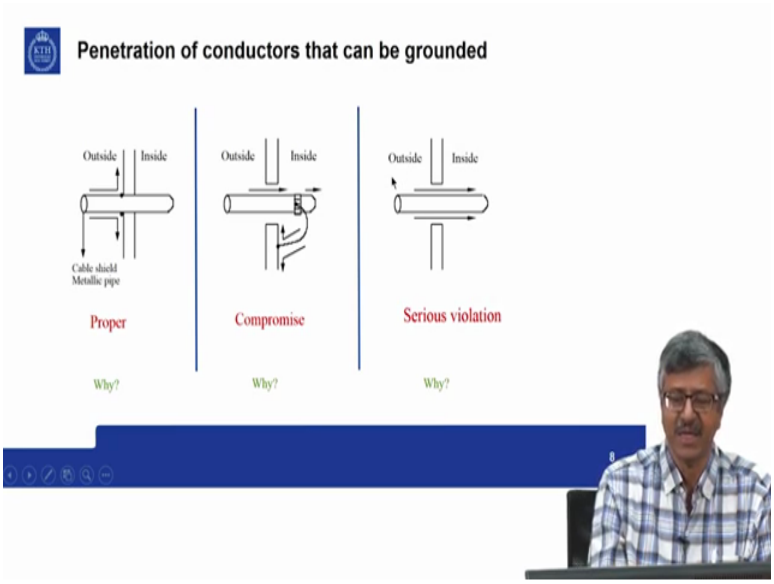

Then sometimes you have water pipes coming inside they are not grounding conductors but it can be grounded because they are metallic. So most proper way of connection is like this you just do a 360 degree bonding of the pipe to the (metal plate) metal sheet through which there is a hole, so there is no hole here so all the currents are currents coming through (())(16:23) currents coming through the water pipe is outside or it can be a cable shield also so that can be (())(16:30) currents in the cable shields and that is confined to the outside.

Now this could be a compromise connection because often you cannot match exactly the plate and this pipe and there can be thermal expansions and things like that so there may be some gaps between them so you can put a metallic strap around clamp around and connect it to the inside or outside preferably outside and this is a serious violation so this should now be allowed because there is no zone separation between outside and inside.

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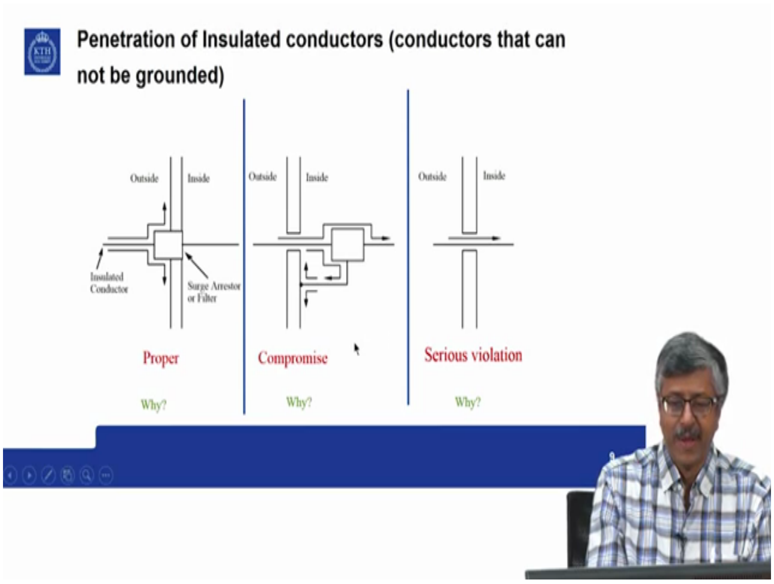

You can have insulated conductors penetrating a zone boundary. For example it can be a power cable or a data cable. So in that case often you may have a filter and surge arrestor unit also confined to a box, then this is the most proper way of connection you connect the filter in (())(17:51) with this so that noises are confined to the outside and this is a serious violation without any filters or surge arrestors directly taking into the power cable through it and this is the compromise if you cannot connect (())(18:14) with it you can do it in this particular way also.

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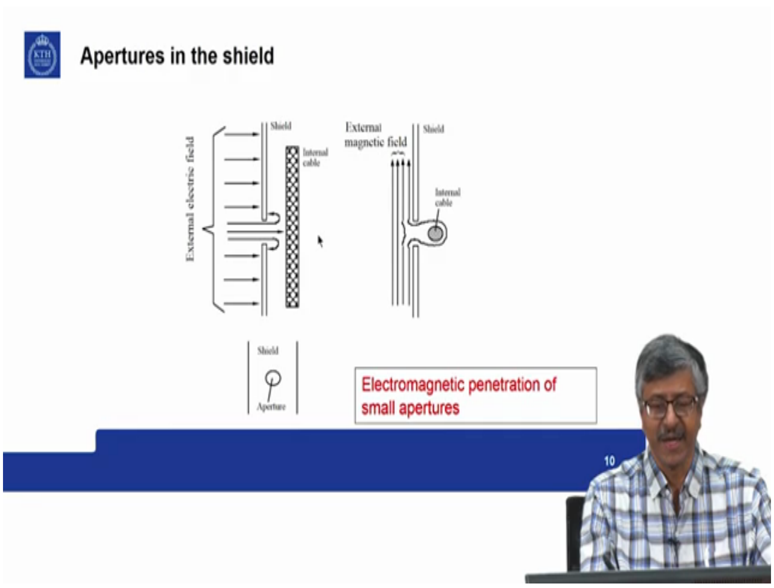

Often you need apertures in the shield because you need to have air circulation between outside and inside, there may be electronics that may get heated up so you need to have cooling and you need to take in fresh air or if it is huge (())(18:47) people may be working inside and they need fresh air also so you will or for lightening purposes or whatever reasons you may have several apertures on the shield.

So how do you control those apertures if you want to have inside and outside as two separate zones, so the problem with apertures is that suppose if you have a cable running along the aperture then you will have field terminating over the cable and inducing some voltages and currents on it. So this is electric field, what is shown here and this is the magnetic field coupling with the internal cable.

So larger the aperture more this type of (())(19:43) penetrating the aperture. Now how do you handle those apertures? How can you reduce those fields penetrating?

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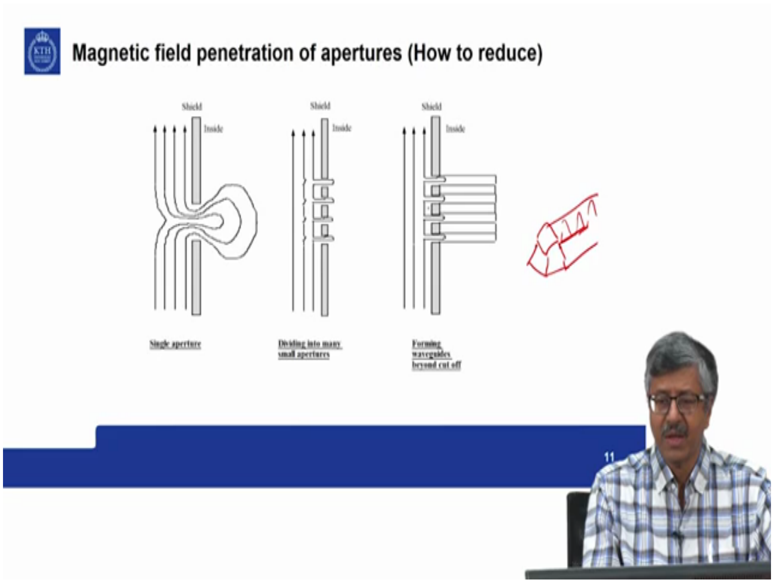

So one way is that you divide these holes you need certain surface area for the hole to have proper ventilation let us say. So instead of providing one hole you provide a series of holes or a mesh so there are many small apertures then the field penetration is much less and often you can form waveguides beyond cut-off so this we will see it later while talking of shielding, but waveguides are this type of honeycomb structures say across many instruments you might have seen these type of structures like this honeycomb like and with a depth to it.

So those structures are for fields to be propagating and there will be multiple reflections and all then they will be attenuating, so this is called waveguides so that will reduce the field by the time it is coming out, sometimes it is completely cuts-off the fields. So in across many instruments the (())(21:33) you can find these type of structures.

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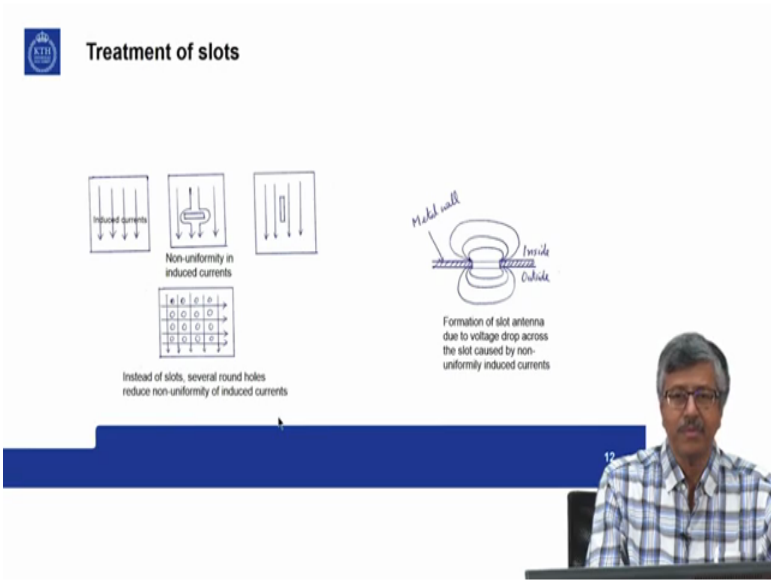

Then if you have slots the orientation of slots become important and if you know that induced currents are in this particular way this is not and if there is a slot like this the induced currents are non-uniformed and that will create the potential difference across the slot and you will create a kind of a slot antenna due to the voltage drop across so this will radiate both to inside and outside and create problems.

So with this type of slot or (())(22:22) you may reduce that, but if it is possible to have several small holes then you will not disturb the induced currents too much and you will not form this type of radiating antennas on the metal surface. So instead of slot several round holes reduced on uniformity of induced currents so this is one way of reducing the problem of slots.

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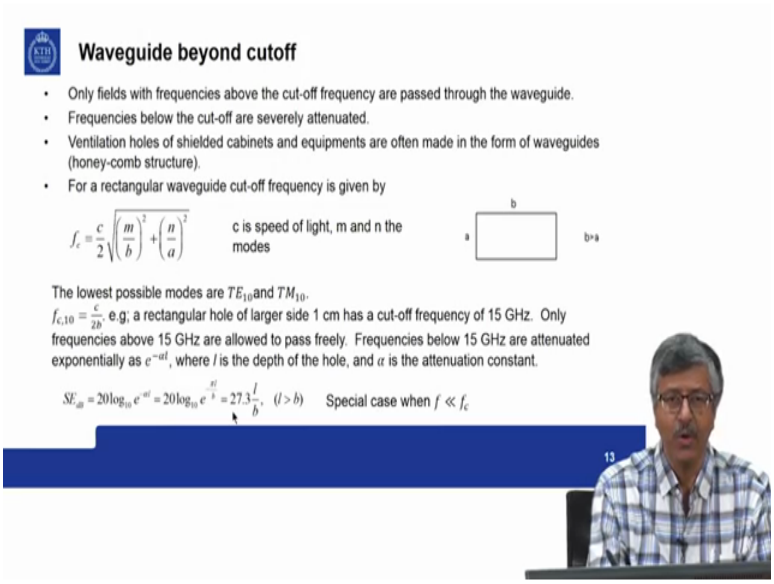

Now waveguide beyond cutoff, the principle is like this. Suppose you have a rectangular cross section waveguide and it has got a depth of length l, the length of the waveguide, now b is greater than a let us assume, only fields with frequencies above a particular cut-off frequency are passed through the waveguides and all those frequencies below that cut-off frequency will be attenuated.

So what will be those cut-off frequency? So from the theory of electromagnetics you can find it in electromagnetic textbooks that frequency is given by this formula, the cut-off frequency equal to speed of light divided by 2 square root of m is a mode number, m and n are mode numbers and b and r are the dimensions of the slot, m by b square plus n by a square, so this is the cut-off frequency.

So the lowest possible modes for waveguides are transverse electric and mode 1 0 and transverse magnetic mode 1 0. So m will be 1 in TE and n will be 0. For example if you take a 1 0 mode f c 1 0 rather it is electric or magnetic then you get this expression as c by 2b this part is 0 and this is 1. Now imagine a rectangular hole of larger side that is b equal to 1 centimetre so if you put b here then c by 2 is 1.5 newton to power of 8 metres you know so many per second, so b is 0.01 meter, so that frequency is 1.5 10 to power of 9 so it is 15 Giga Hertz, only frequencies about 15 Giga Hertz are allowed to pass freely.

So frequencies below 15 Giga Hertz are attenuated exponentially as e to power of minus alpha l, where alpha is attenuation constant and l is the depth of the hole. So for this particular case we can see that you know attenuation in terms of db 20 log e to power of minus alpha l, so e to power of pi l by b so 27.3 l by b, l is the length and b is the largest dimensions of the waveguide when l is greater than b. So you can see that these waveguides provide quite good attenuation to the fields penetrating a hole.

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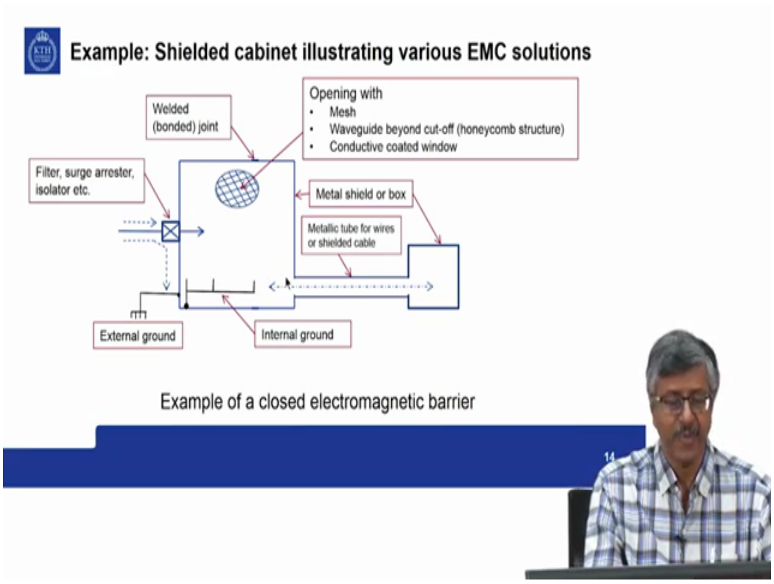

Now consider a shielded cabinet so this type of shielded cabinets are often used in measurements sensitive measurements in the laboratory in high voltage labs and control rooms of several power stations or other kind of industries. So let us illustrate various concepts we have seen so far into this, say for example this is the main cabinet and you have an (())(27:33) system another small control unit, so these two so outside you have one particular zone and you want to treat the whole area inside as a single zone as second zone.

So you have metallic tubes for wires or shielded cables connecting these two, so all these are in the single zone so these are metal shield or box. Now for (())(28:04) you treat with mesh, or waveguide beyond cut-off honeycomb structure, you can even have conductive coated windows, if you need to have light and if you want to observe things outside, then welded joints this is the external grounds, internal grounds are shown here and any conductors penetrating you have to treat as we have seen before on conductor penetration.

So this is an example of a closed electromagnetic barrier designed according to zoning principle then you can have your equipments inside without getting interfered from outside or creating interfere to the outside.

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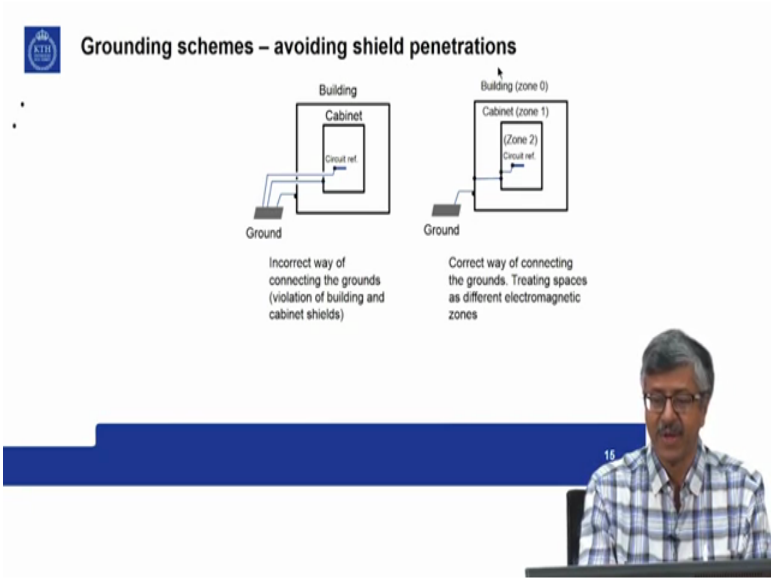

Now often you can have a building, then inside the building you have a huge control room or a cabinet, then inside you have several equipments and circuits, etc and there may be several grounds equipment ground, cabinet ground, building ground, so how do you at the same time you want to bond these grounds also so that during transients you do not have potential differences between them.

So this is the incorrect way of treating it cannot have just have an external ground and connect everything together to that because now you are violating all the zoning principles. So this is the correct way of treating those grounds, circuit reference is connected over here confined to the zone 2, this is the cabinet in zone 1, these two are bounded together and a zone 0. So you really have to have this thinking in terms of electromagnetic zones while designing these grounds.

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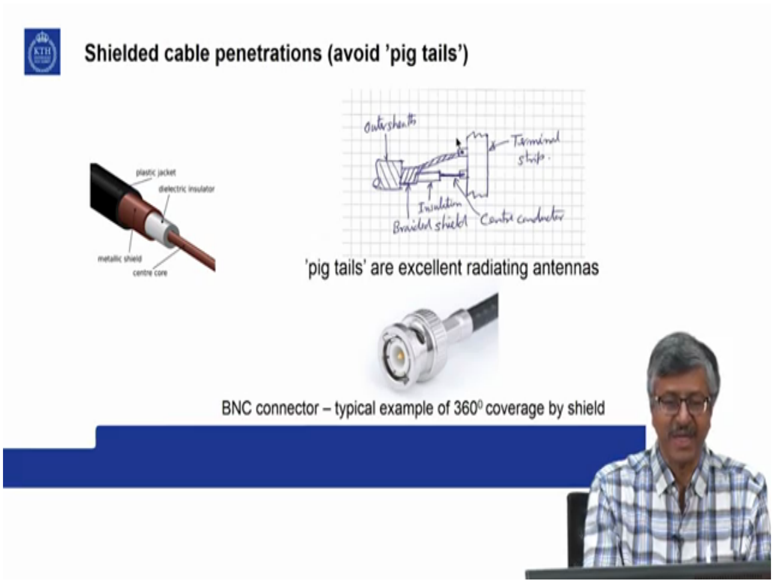

So pig tails are favourite for most engineers because if you want to connect a cable to some equipment the easiest thing is remove the insulation or take the inner conductor, then take the shield you know and form a pig tail and connect it like that of course functionally this is okay but not from a EMC point of view electromagnetic interference point of view because now you are creating a nice loop antenna or a dipole antenna depending upon how you see that which can radiate and create problems. So in labs you always have this BNC connector which gives a typical 360 coverage by the shield so that will be the proper way of connecting it, so this is end of module 1.