

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 :12
Lecture 56: Grounding (Continued)

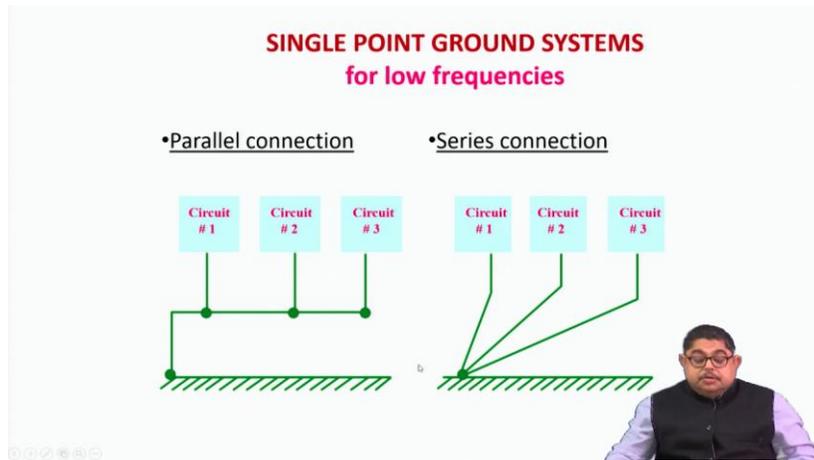
Welcome to the lecture of the course on EMI, EMC and Signal Integrity Principles, Techniques and Applications. We are continuing our discussion on grounding. So, various types of grounding schemes you can have single point grounding, you can have multipoint grounding, you can have hybrid grounding, you can have floating grounding.

VARIOUS TYPES OF GROUNDING SCHEMES

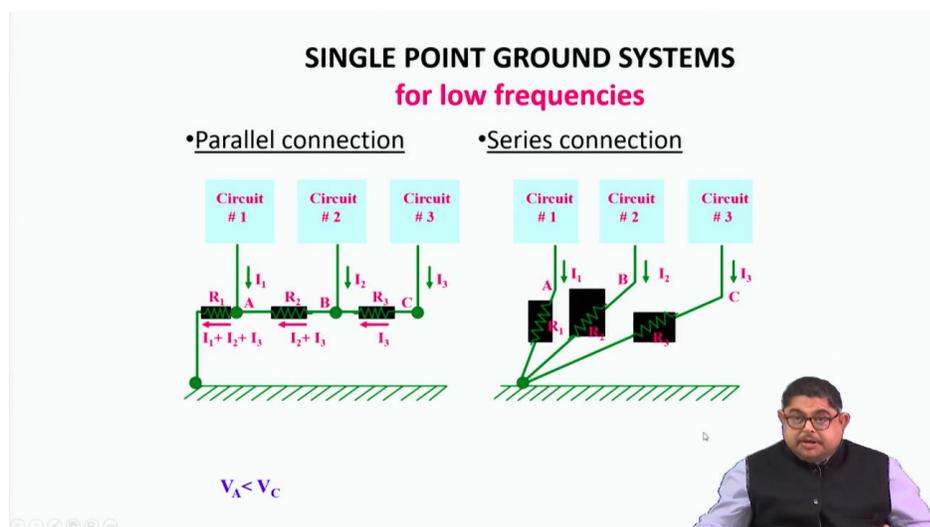
- Single point grounding
- Multi point grounding
- Hybrid grounding
- Floating grounding



Let us see them one by one. Single point ground systems, these are used for low frequencies, you can have a parallel connection, you can also have a series connection. Now, in parallel connection let us assume that we have three circuits whose grounds are available. So, in parallel one they are connected in this fashion, they are all parallel and that one is taken to the actual ground. In series they are all connected individually to the ground.



Now, in parallel connection actually there is a whenever you are connecting it, you are having a resistance, here also you are having a resistance, here also you are having a resistance. So, whatever I_3 is coming, now after this point B you are having I_2 plus I_3 after, now it is not going to the circuit because this is a low impedance path. So, always it is seeing this and going here, we are assuming all the currents are going here that is true because this is a very very low impedance path. I_2 plus I_3 then it after here it goes to I_1 plus I_2 plus I_3 , whereas here I_1 goes directly to ground, I_2 goes directly to ground, I_3 goes directly to ground. These resistances are due to these leads or these wires whatever you use to connect that time there is a resistance and you see due to this V_A is always less than V_C for this part, this is here V_A is equal to V_C it may be if the circuit 1 and circuit 3 are of same potential, their grounds are of same potential.



Features of single point grounding suitable for low frequency circuits reduces the common mode noise requires long conductors because you see that everything is done through these conductors. So, long conductors in it is costly not feasible at high frequencies because those conductors etcetera they will be susceptible to radiations at low frequency there is no radiation. So, this scheme works.

FEATURES OF SINGLE POINT GROUNDING

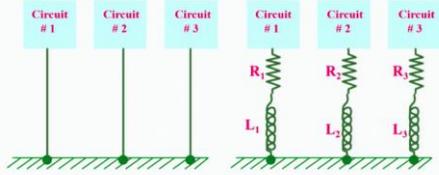
- Suitable for low frequency circuits
- Reduces the common mode noise
- Requires long conductors, hence costly
- Not feasible at high frequency



Now, multi point ground systems, they are generally above 10 megahertz these are done. So, high frequencies and also digital circuits come here because in digital circuits there is a on off mode. So, there lot of if you take the clock etcetera there have a lot of high frequencies. So, that is why for them also this is the connection. So, you just have that you will have to give an R 1 L 1 to it R 2 L 2 to it that means an R L choke you will have to put.

MULTIPOINT GROUND SYSTEMS for high frequencies & digital circuits

•Multipoint ground connection



Effective above 10 MHz



So, suitable for high frequency circuit simplified the circuit construction cable interface etcetera you will have to only provide those components at the frequency in which you are operating. Problem of conductively coupled L F common mode noise that will come here because you have that low frequency common mode noise on gate eliminated here, ground loops created are prone to radiated pickup. You are having ground loops you see these ground loops will be prone to radiation pickup.

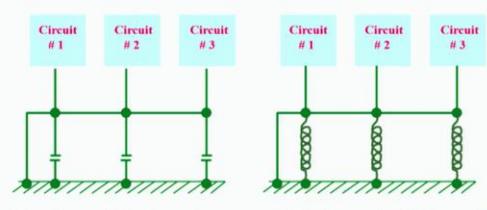
FEATURES OF MULTI POINT GROUNDING

- Suitable for high frequency circuits
- Simplifies the circuit construction, cable interface, etc.
- Problem of conductively coupled LF common mode noise
- Ground loops created are prone to radiated pickup



So, a better scheme is how to combine this single point and multiple point. So, you see that you have a direct connection also with that you can either put a capacitor or in this case either put an inductor. So, here what will happen you see that at low frequencies you are due to the presence of these capacitors you are getting a single point ground at low frequencies and at high frequencies you are getting a multi point ground. So, that is the beauty similarly here a due to the inductor a single point ground at high frequencies and a multi point ground at low frequencies. So, this is a nice scheme different at different frequencies you get the thing.

HYBRID GROUND SYSTEMS different at different frequencies

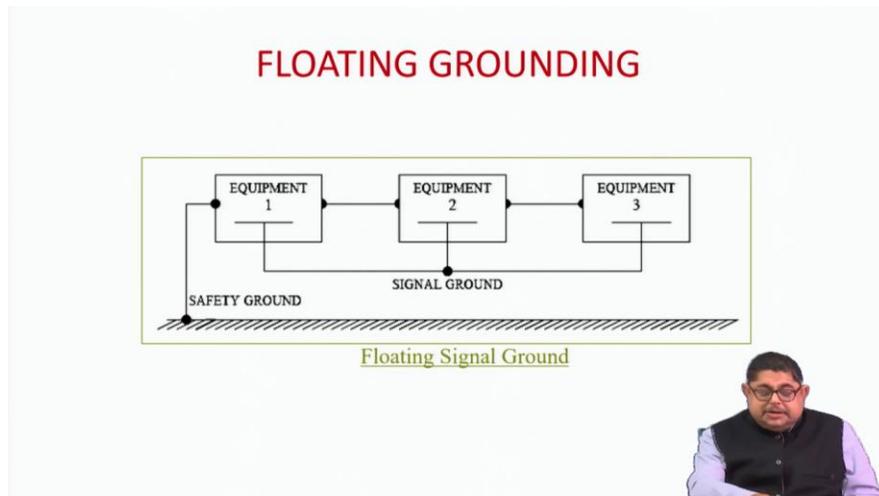


A single point ground at low frequencies.
 A multipoint ground at high frequencies.

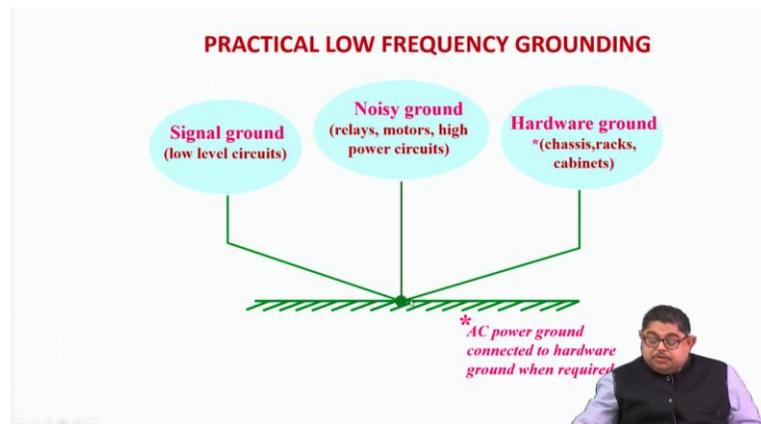
 A single point ground at high frequencies.
 A multipoint ground at low frequencies.



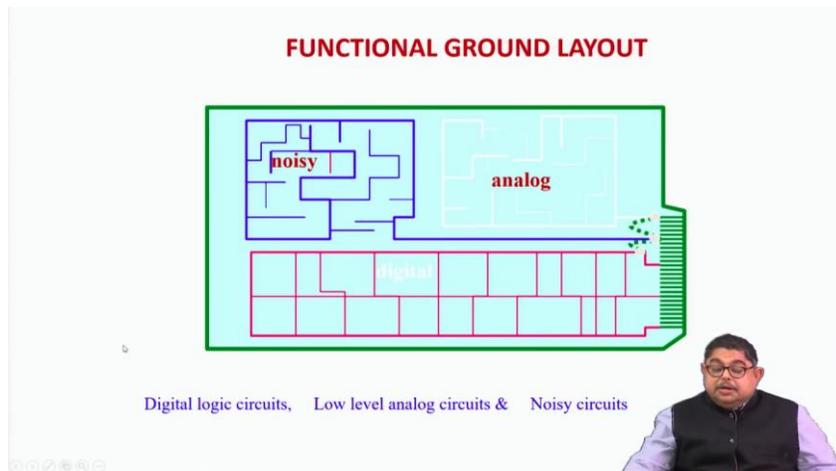
Floating grounding here because in some systems you cannot physically ground. So, signal ground you take and put it to a safety ground that safety ground these are the examples of suppose in aircraft suppose in ships how you ground because you are not seeing the ground. So, there this safety ground is there and that safety ground when required because when it is when the aircraft is flying or when the ship is sailing that time there is no problem because only when it will come in contact with the ground when a ground means our earth that time there will be problem. So, when the aircraft come this safety ground is then connected to the ground by that all the charges accumulated here that goes to the ground.



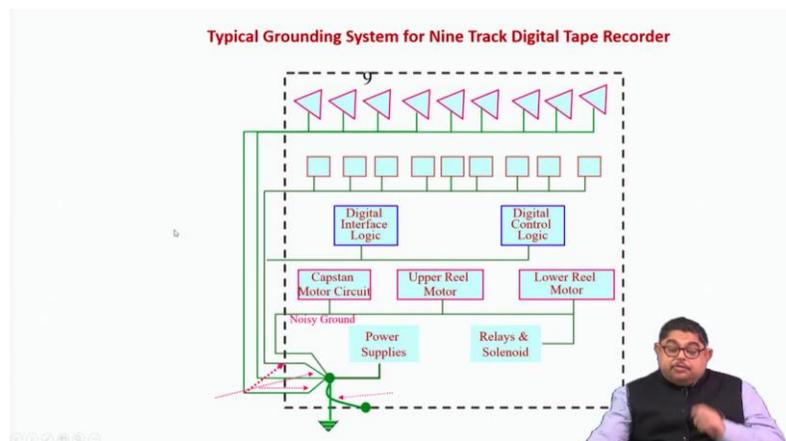
So, practical low frequency grounding signal ground noise ground hardware ground now these are all should be connected together and that connect to the AC power ground this is hardware ground and that is connected to AC power ground when required .



this is the functional ground layout for digital circuits. This part is analog this part is noisy this part is digital circuit .

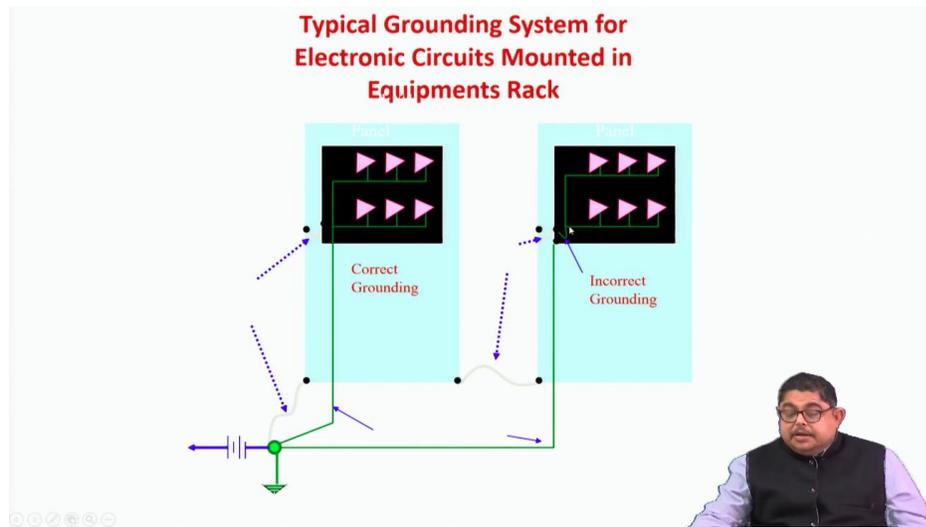


this is a typical grounding scheme for a nine track digital tape recorder these are just to show you that in practical cases there are noisy grounds etcetera there are digital grounds.



Then typical grounding system for electronic circuits mounted in equipments rack now there you see never this incorrect grounding you see that here the components their ground is connected to the rack this is not to be done rack will be connected to chassis. So, if the chassis is getting lot of noises etcetera. So, by this actually whole of your those from rack they will come to your digital components whereas, correct method is this component ground that you directly connect to the ground the racks etcetera they will be

connected to the chassis. So, that is why these components are isolated. So, this is called correct grounding and this is incorrect one.



Frequency dependence grounding we have seen already that that below 1 megahertz a single point ground is preferred above 10 megahertz a multipoint ground is based between 1 to 10 megahertz a single point ground you can use provided length of largest ground conductor is less than $\lambda/20$ then it would not pick up the radiation and a multipoint ground is required if that conduct maximum conduct largest ground conductor that is above this value because then it will get radiation. So, that you will be using that R L circuit etcetera to choke that .

Frequency Dependence Grounding

- Below 1 MHz a single point ground is preferred.
- Above 10 MHz a multipoint ground is best.
- Between 1 to 10 MHz
 - a single point ground provided length of largest ground conductor $< \lambda/20$.
 - a multipoint ground provided length of largest ground conductor $> \lambda/20$.

some good grounding practices signal ground should be connected to power ground at single point not at various points that will then your grounding would not be proper single point grounding for low frequency systems power audio systems control system multipoint grounding for high frequency systems that is RF communication navigation etcetera use of hybrid grounding as per situation demands use minimum length and sufficient cross section of grounding conductors as far as possible minimum length and sufficient cross section. So, that the resistance is minimized proper routing of grounding conductors for minimum coupling that we have shown that for lightning arrestors etcetera how to do that use of twisted shield cables for signaling shield grounded cables. Now, that is said, but that will be many times you it will increase your cost, but as a technical solution that use of twisted shield is always recommended.

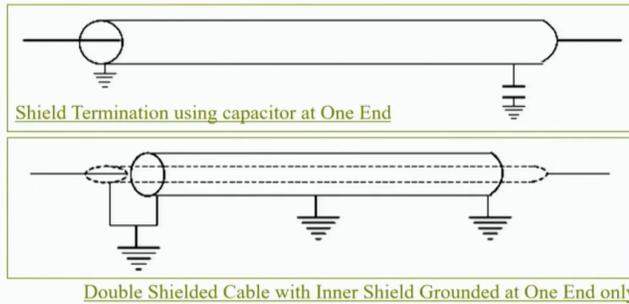
SOME GOOD GROUNDING PRACTICES

- Signal ground to be connected to power ground at single point
- Single point grounding for low frequency systems (e.g. power, audio, control systems)
- Multi point grounding for high frequency systems (e.g. RF communication, navigation, etc.)
- Use of hybrid grounding as per situation demands
- Use minimum length & sufficient cross section of grounding conductors as far as possible
- Proper routing of grounding conductors for minimum coupling
- Use of twisted shielded (shield grounded) cables for signaling

(contd.)

Now, shield termination using capacitor at one end this is the shield. So, now double shielded cable with inner shield grounded at one end only. So, this is you see that double shielded cable. So, this is very good use of isolation techniques also that will come that for other cases where the apart from this conductors.

SOME GOOD GROUNDING PRACTICES

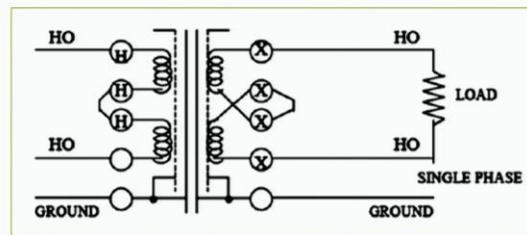


- Use of isolation techniques viz. isolation transformer, F0 cables

(contd.)

this isolation transformer with grounded shield. So, you see that the voltage high voltage is coming this coming there is a isolation transformer. So, its choke is also properly designed. So, that this two there is a very high isolation between the two parts and periodic maintenance and performance check of this isolation because if this isolation is not there if some fault come from the power side you are gone, but if many things huge fault comes in the power side like I am telling you an experience that there was an exam being conducted I was there. So, the suddenly in the power transformer that one bird he shorted the phase and neutral. So, through neutral huge a came, but there was isolation transformers. So, there was not much damage within half an hour I could start the examination again because all the equipments were getting functional once the power supply got restored. So, that happened in an all India that JEE examination just two three years back. So, this isolation transformer is very very required.

SOME GOOD GROUNDING PRACTICES



Isolation Transformer with Grounded shield and Core

- Periodic maintenance & performance check of grounding system

now plus platform specific grounding practices. So, ship borne air borne ground based. So, they are different as I was saying that ship borne how to do air borne how to do ground based we have seen more or less.

PLATFORM SPECIFIC GROUNDING PRACTICES

- Shipborne
- Airborne
- Ground based
 - Shelter based
 - Vehicle mounted
 - Tracked vehicle



So, grounding in ship always there you should use three phase four wire y connection and safety ground should be there will be a safety ground where all the systems are connected. Now, prior to refueling for refueling the ship is that is then when danger point is that because that time when it is refueling this grounding system that may get through that the high voltage may come. So, safety ground at the ship's hull generally at the hull of the ship this safety ground escape that should be somehow connected to the refueling systems ground and use of ground shorting probe for waste cables for personal safety. So, ground shorting probe that means whether the ground is giving what type of voltage that you should check whether that is permissible for your ship that should be checked because otherwise the persons who are in those doing those refueling they will be in danger.

GROUNDING IN SHIP

- Use of three phase 4 wire wye connection
- Provision of safety ground at the ship's hull prior to refueling
- Use of ground shorting probe for hoist cables for personal safety



Now, if the hull is nonmetallic because nowadays the hull of the ships are getting nonmetallic then use submerged exterior metallic plates. So, metal plates you give and sea water is saline. So, the resistivity is quite small. So, that will help you or even if nothing is available the engine there will be a metallic part. So, that you can put as ground plate. So, during refueling or other need safety ground had been connected to that.

NON METALLIC HULLED VESSELS

- Use of submerged exterior metallic plates
- Use of engine block as the ground plate



Airborne specific grounding as it is power supply 3 phase 4 wire with coating neutral, neutral not to be disconnected at servicemains. So, special contraction of construction of neutral connection and necessity of grounding aircraft and fuel bowser during refueling that same that always this refueling is a very very dangerous business because that time it is coming in contact with ground or with if it is done on air then the two aircrafts their grounding systems is coming in contact. When they are alone that is not a problem, but this time the refueling systems ground and this ground if there is a large potential and that happens because there are various pitch static etcetera specific static. So, one aircraft may have connected a lot of charges. So, that time there may be huge current exchange.

AIRBORNE SPECIFIC GROUNDING

- Power supply
 - 3 phase 4 wire with floating neutral
 - Neutral not to be disconnected at service mains
 - Special construction of neutral connection
- Necessity of grounding aircraft & fuel bowser during refueling



These are ground base specific grounding. So, desired grounding resistance is less than 25 ohm in all ground base systems you should ensure that less than 25 ohm. It achieving is quite difficult quite costly etcetera. In our lab we also do precise measurement, but we cannot achieve 25 ohm, but 40 ohm we achieve. So, laboratory etcetera 40 ohm still now we are getting though this is 25 ohm, but we have seen that for that you will have to have a good soil etcetera that I am coming. So, achieving these, but 25 ohm means you are having a very good ground.

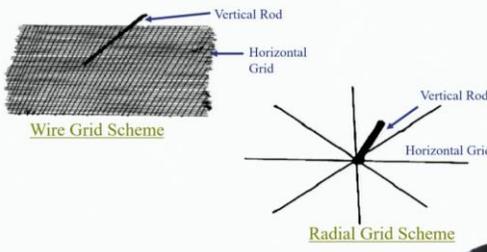
GROUND BASED SPECIFIC GROUNDING

- Shelter based system
 - Separate electrodes for signal & safety grounding
 - Desired grounding resistance : $< 25 \Omega$
 - Use of solid ground rods in the configurations such as
 - ring of rods around the shelter
 - wire grid scheme



So, these are in ground you can use these wire grid schemes and the vertical rod is there is a horizontal grid of metallic meshes and then this vertical rod that is going to take you the ground line. This mess you put inside the that hole or well you can say that you have dig it at least 5 10 feet and then you put it there or you can give get this instead of this mess putting mess will be may become costly. You can put some horizontal rods actually in antennas also sometimes this is done for grounding. So, and this is the vertical rod which is taken out which behaves as a ground. So, solid plates are used for least resistance. So, this is there are also some calculations that how many such rods will be there typically 6 or 12 rods people use.

GROUND BASED SPECIFIC GROUNDING (contd.)



- solid plates for least resistance



Then lightning arrestor you have said now always the lightning arrestor should be placed well above antennas because before that if they are below that means antennas will pick up the lightning first. Some antennas are quite high, but lightning arrestors should be higher. Avoid parallel running of antenna cable with grounding strip of lightning arrestor. Power conditioners to take care of transient in power lines. So, even if some transient comes there should be power conditioners since the transients are for very short time for that very short time it will not allow anything to go.

LIGHTNING ARRESTER GROUNDING

- Transient aspects
 - Provision of LA well above antennas
 - Avoid parallel running of antenna cable with grounding strip of LA
 - Power conditioners to take care of transients in power lines



Grounding for ESD here if you go to any fabrication lab etcetera nowadays those VLSI labs there you will have to create an ESD environment with mats they use special mats they use special type of floor. So, that any charge if you anyone carries that gets dissipated there. Use of ionizer so that the charges before entry these are used. Separation of ungrounded metallic objects touchable by operator. Operator should not touch any metal electronic component without grounding itself for that they use some wrist band sometimes some gloves etcetera also some cap. So, all these are for creating that grounding environment for ESD.

GROUNDING FOR ESD

- Creation of ESD dissipative environment with mats, floor, etc.
- Use of ionizer
- Separation of ungrounded metallic objects touchable by operator
- Operator should not touch any metal/electronic component without grounding himself



Now, we come that the ground resistance you are seeing that for grounding we need to make the ground resistance very low. So, that ground resistance depends on soil. So, soils resistivity depends on soil type, moisture content of the soil, temperature of the soil. Now, soil type it depends, but you cannot do whenever we select a site generally we do not pay attention to what is the soil type whether that will give good grounding because other considerations prevail there. But if you can pay attention there that will be very very nice, but generally that is not in your hand.

GROUND RESISTANCE DEPENDS ON SOIL

- Soil resistivity depends upon
 - Soil type
 - Moisture content of the soil
 - Temperature of the soil



Now, type of soil you see loamy soil, garden soil their earth resistivity is 5 to 50 etcetera concrete, clays, clay sand and gravel mixtures like that. Rocks are very high earth resistivity. So, that means on rock rocky area or on sandy area getting a ground you will have to labour lot, you will have to incur huge cost whereas, in our loamy soil you will be much better.

EARTH RESISTIVITY FOR DIFFERENT TYPES OF SOIL

Type of Soil	Earth Resistivity (Ωm)
Loams, Garden Soils	5-50
Concrete	30-90
Clays	10-100
Clay, Sand and Gravel mixture	30-100
Marsh Peat	40-250
Sand	150-500
Slates and Slatey Shales	300-3000
Rock	1000-10000



Then effect of moisture content on earth resistivity. So, there also you see that resistivity in milliohm. So, it is quite that means this much percent by weight 30 percent. That also gives you 100, but there is a variation. So, you should pay attention to that also.

EFFECT OF MOISTURE CONTENT ON EARTH RESISTIVITY

Moisture Content (Percent by Weight)	Resistivity (Ωm)	
	Top Soil	Sandy Loam
0	107	107
2.5	2500	1500
5	1650	430
10	530	220
15	210	130
20	120	100
30	100	80



Temperature, so you see lot of resistivity is varying for temperature and in old countries the resistivity is high because they are having low temperatures, they are the resistivity is quite high.

EFFECT OF TEMPERATURE ON EARTH RESISTIVITY

Temperature ($^{\circ}\text{C}$)	Resistivity (Ωm)
20	72
10	99
0 (Water)	138
0 (Ice)	300
-5	790
-15	3300

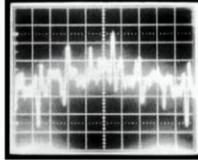


And this is a if we measure actually that noise voltage should be measured. So, typically a ground network noise looks like this. This is the low frequency case left side, the right side is high frequency case. In an oscilloscope it is being shown. So, vertical is this. So, roughly you can say that 1, 2, 2 and a half. So, 50 milli volt is the noise voltage and frequency you can get from this horizontal reading and here also 2 and a half, so roughly that 30 milli volt is a thing. So, with this we close our discussion on grounding today. So,

we will see other 2, 3 electromagnetic compatibility considerations in our next classes.
Thank you.

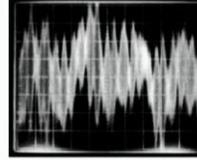
TYPICAL DIFFERENTIAL NOISE VOLTAGE IN GROUND

Vertical: 20mV/div
Horizontal: 2ms/div



Periodic Ground Network Noise

Vertical: 10mV/div
Horizontal: 2ms/div



RF Ground Network Noise

