Testing of Functional & Technical Textiles
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Lecture – 24
Testing of Electromagnetic Shielding Textiles

Hello everyone. So, we have reached almost at the end of this course, today we will discuss the last topic of the course Testing of Functional and Technical Textiles. The topic we will discuss today is Testing of Electromagnetic Shielding Textiles. So, first we will try to understand what is electromagnetic shielding and why do use textile materials.

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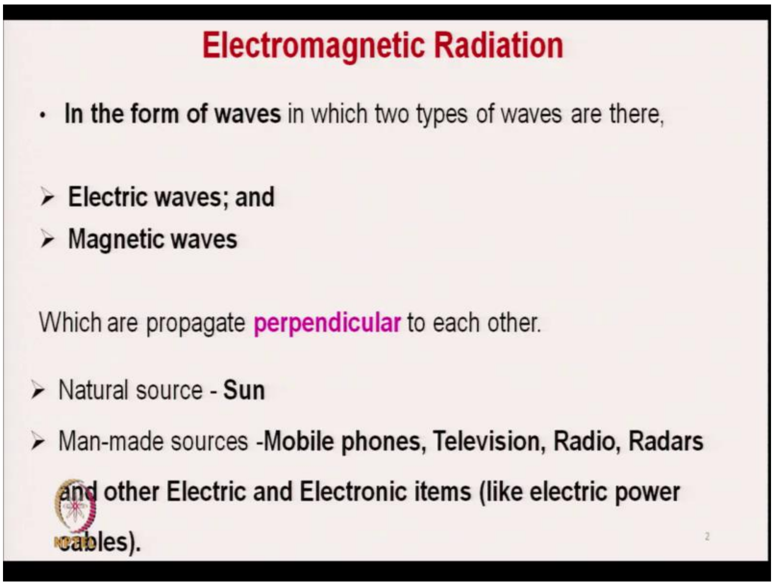

So, electromagnetic radiation it is in the form of wave in which there are two types of waves are there; these are electric waves and magnetic waves. And this waves propagate perpendicular to each other and also they are perpendicular to the direction of propagation. There are different sources of electromagnetic radiations like most common natural source is sun and manmade sources are like mobile phones, television, radars, radio and other electrical and electronic items like electric power cables there are many other sources.

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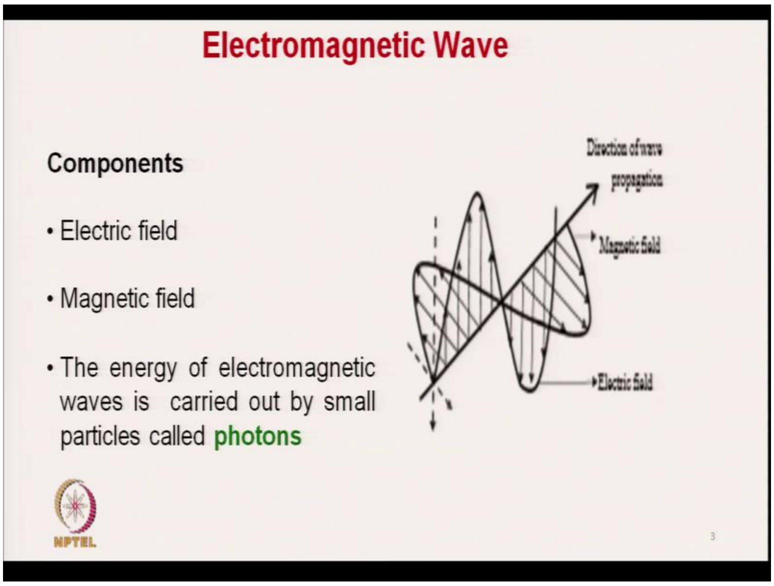

So, this components are electric field and magnetic field and the energy of electromagnetic waves is carried out by small particles which is called photons so, they are carrying the energy. And here in this picture we can see here, this graph is showing electrical field and perpendicular to this graph which is showing, it is a magnetic field and these two fields are perpendicular towards the direction of propagation, this is the direction of propagation.

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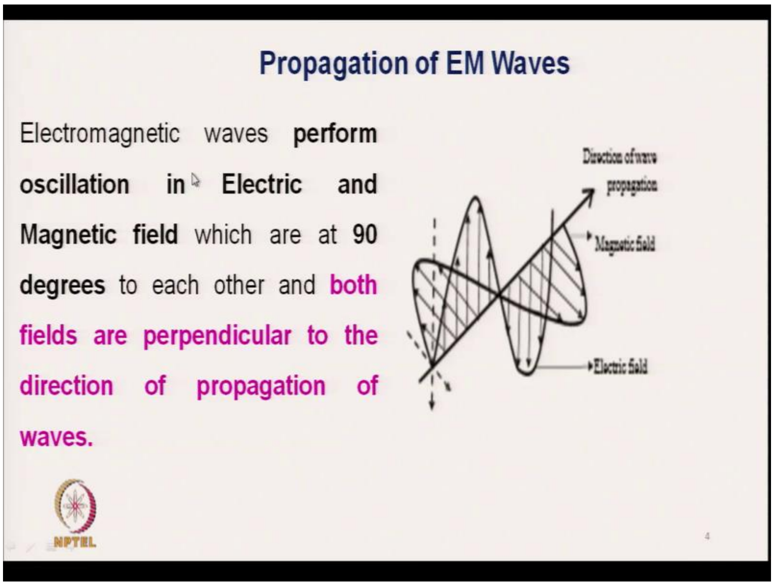

So, electromagnetic waves perform oscillation in electric and magnetic field. So, this is the magnetic field oscillation and this one is electric field oscillation, which are at 90 degree to each other and both fields are perpendicular to the direction of propagation of waves so, this is the direction of propagation of waves. So, we can see here, this magnetic field is going at 90 degree angle, it is making 90 degree angle and also the electric field also it is making 90 degree angle.

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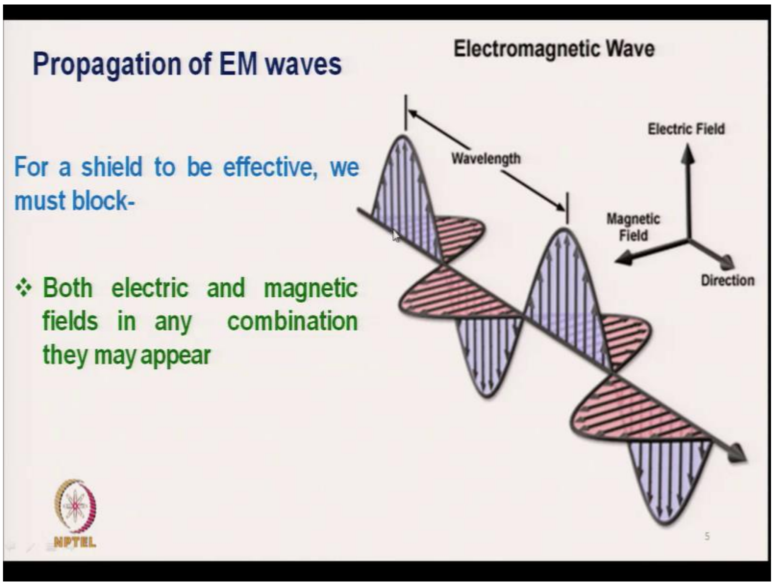

So, the propagation of electromagnetic waves are for a shield to be effective, we must block this propagation. Both electric and magnetic fields in any combination they appear, they have to be blocked. Here we can see, this blue color it is showing the electric field and a 90 degree angle this red color waves, it is showing the magnetic field and this is the direction of propagation. So, we have to block both this electric and magnetic fields.

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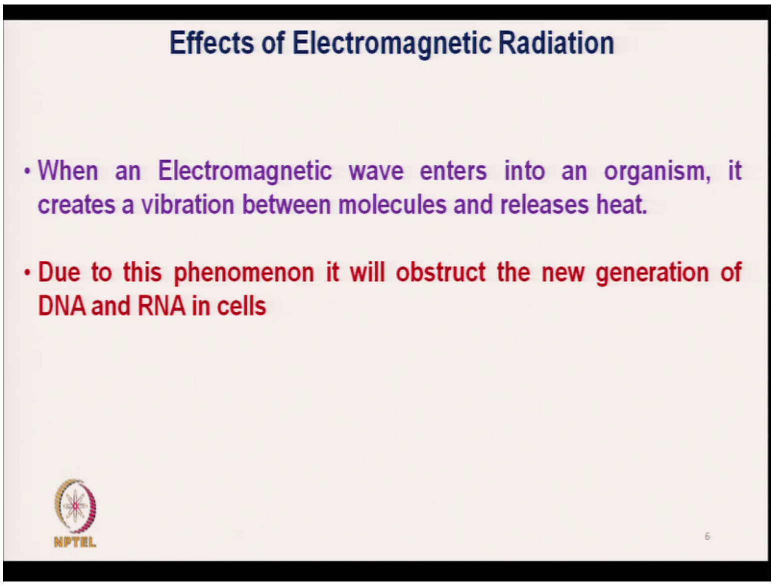

The effects of electromagnetic radiation are so, when an electromagnetic wave enters into an organism, it creates a vibration. So, vibration in the molecules and as the molecules vibrate, they releases release heat; this electromagnetic wave this release heat and due to this phenomena it will obstruct the new generation of DNA and RNA cells in the cells, the DNA and RNA molecules they will actually obstruct.

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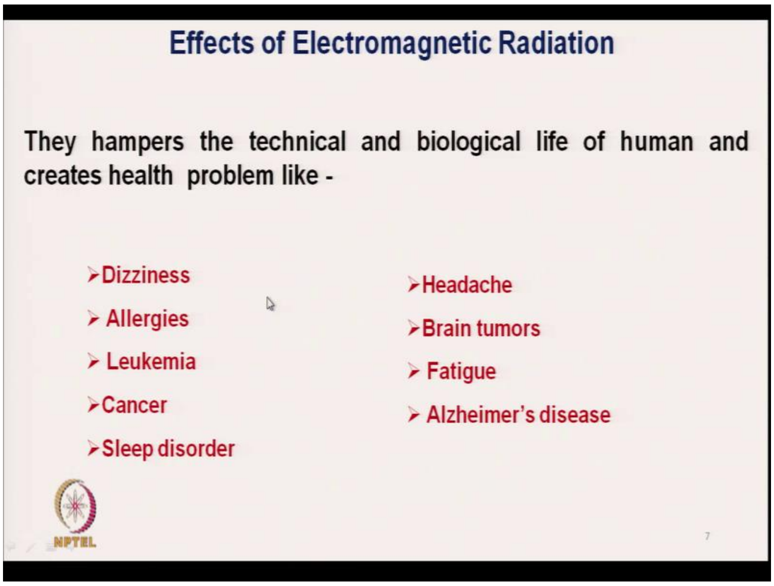

So, they hampers the technical and biological life of human and creates different types of health problems. So, most common health problems due to electromagnetic radiations are dizziness, allergies, even leukemia, cancer, sleep disorder, headache, brain tumors, fatigue and Alzheimer's disease. So, these are the different types of problems which may be created due to electromagnetic radiation.

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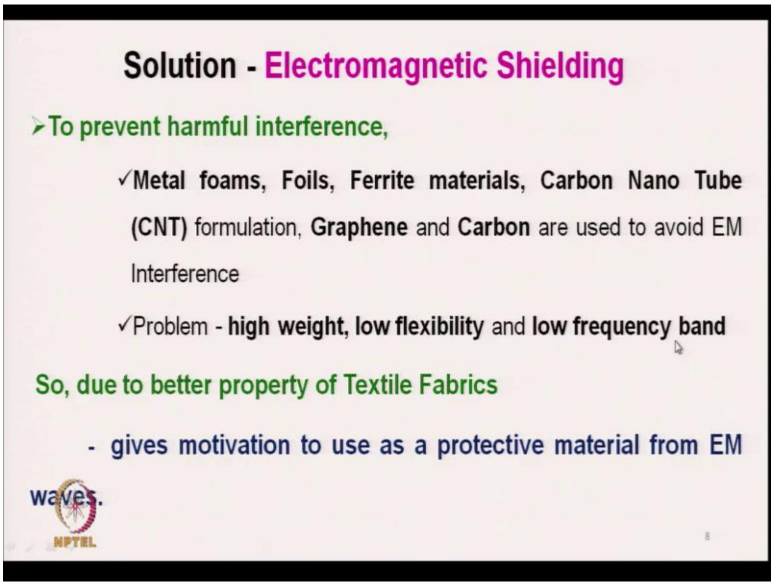

So, what are the solutions? The best solution is that to shield all this electromagnetic radiation. So, to prevent harmful interference of this electromagnetic radiations so, metal foams, foils, ferrite materials, carbon nano tube formulations, graphene, carbons are used to avoid this interference, but main problem with this materials are they are heavier in weight and they are not flexible and they work in low frequency band.

So, best alternative is that, due to better property of textile fabrics, people try to use textile material to protect themselves from electromagnetic radiations.

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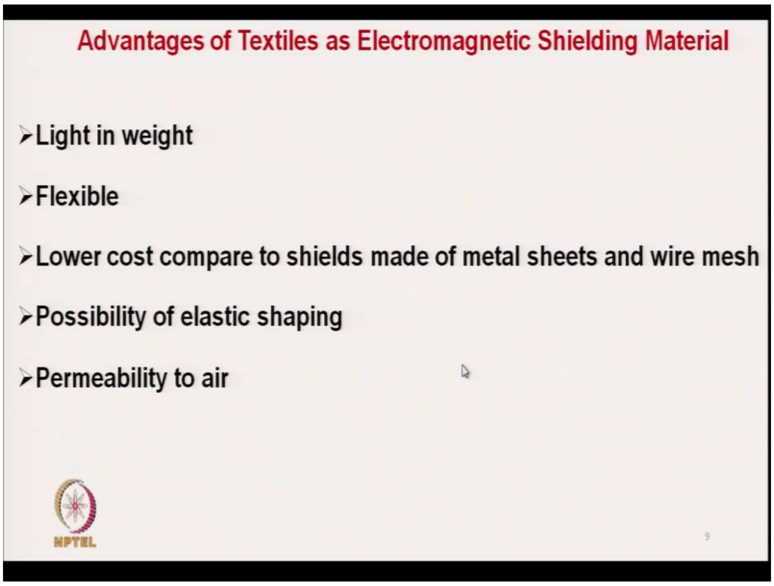

So, basic advantages of textiles as electromagnetic shielding materials are, they are lighter in weight, they are very flexible. So, that this can be used in different applications they are moldable, low cost as compared to other shielding materials, possibility of elastic shaping so, they can be shaped, they can be covered different complex instruments; complex means, instruments of complex shape, even we can wear a fabrics made of electromagnetic shielding material and they are permeable in nature. So, that proper comfort can be imparted.

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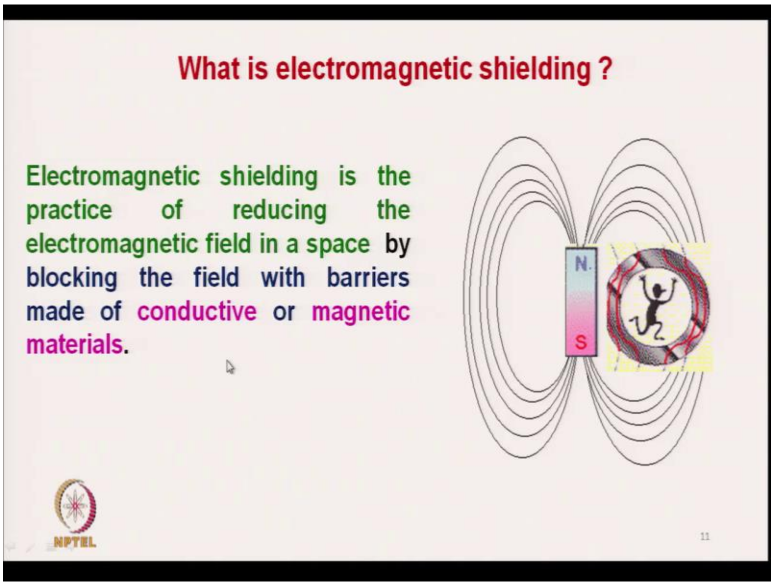

Now, let us try to understand the process of shielding. How do we shield by using shielding materials; basically, electromagnetic shielding is the practice of reducing the electromagnetic field in space, this is the electromagnetic field in space by blocking the field with a barrier material of conductive or magnetic materials. So, magnetic materials or conductive material, if we use we can block this radiation and that is the main function of shielding material.

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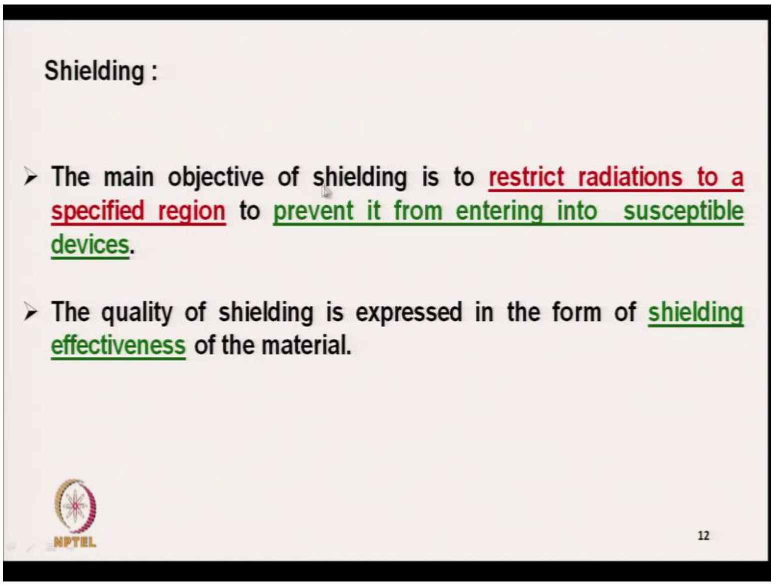

So, the main objective of shielding is to restrict radiations to a specified region. So, we cannot restrict, we cannot stop the radiation entirely, but if we want, we can restrict the radiation in a specified place, to prevent it from entering into the susceptible devices. So, we can prevent this radiation in a particular place where we do not want this radiations to come.

The quality of shielding is expressed in terms of shielding effectiveness. The shielding effectiveness of material, if we can measure, it is expressed in terms of decibel; higher decibel value means higher shielding effectiveness.

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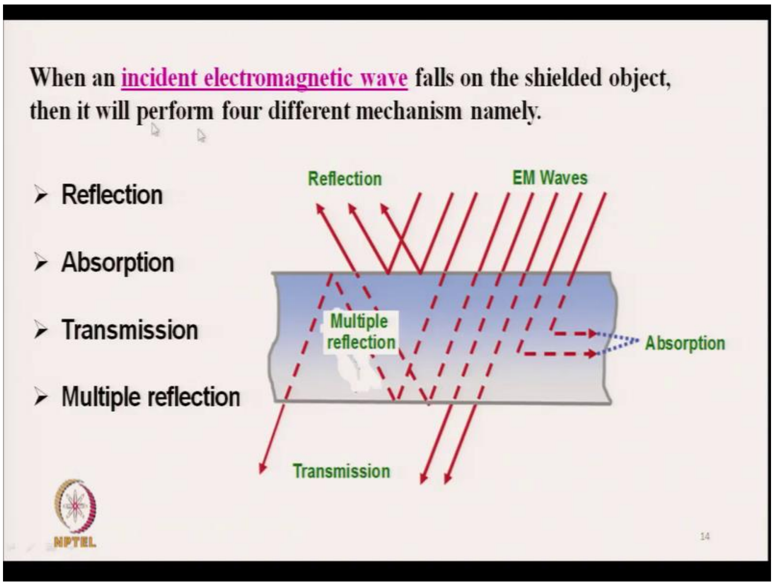

Now, mechanism of shielding; so, this is the electromagnetic wave. So, when an incident electromagnetic wave falls on a shielded object, this is the shielded object. Then, it will perform four different mechanisms, this mechanisms are reflection so, this wave may get reflected and it is not coming on the other side, this is the shield material and this wave may get absorbed by this material, they may be getting transmitted. So, there will be definitely some transmission ideally for perfect shielding material, transmission should be 0 and also multiple reflection.

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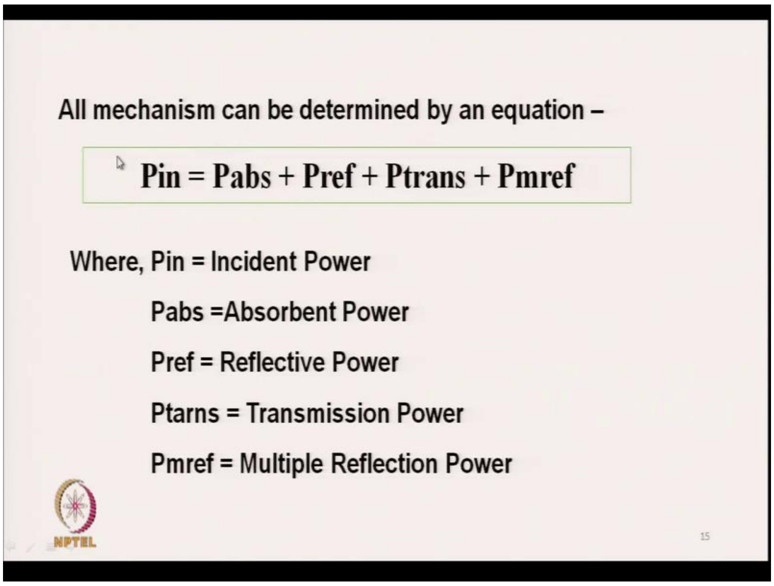

So, all mechanism can be determined by the equations so, total incident power of the electromagnetic wave is the summation

$$Pin = Pabs + Pref + Ptrans + Pmref$$

of absorbent power, reflective power, transmission power and multiple reflection power.

So, if we add all this, we will get the incident power.

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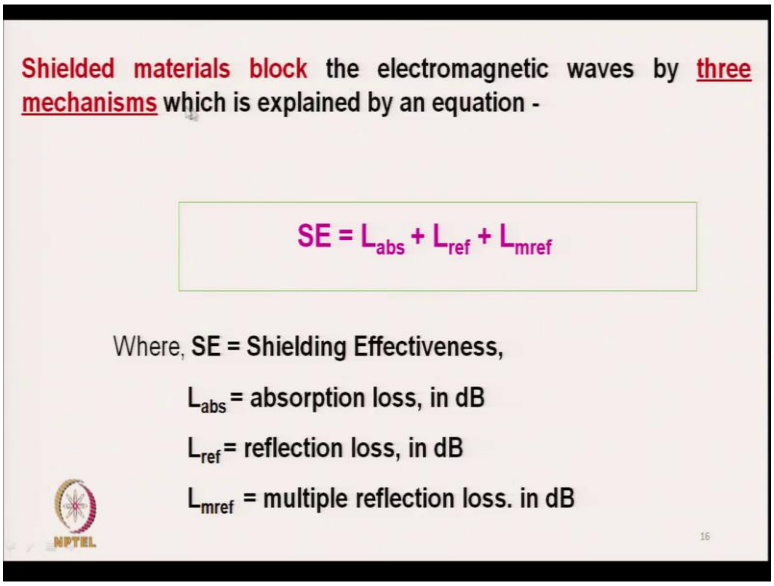

And shielded materials block the electromagnetic waves by three mechanisms as I have already just mentioned, these are absorption loss this absorption loss, reflection loss and multiple reflection loss. So, if we add this losses that will show that, shielding effectiveness. So, higher shielding effectiveness means higher absorption, reflection and multiple reflection loss.

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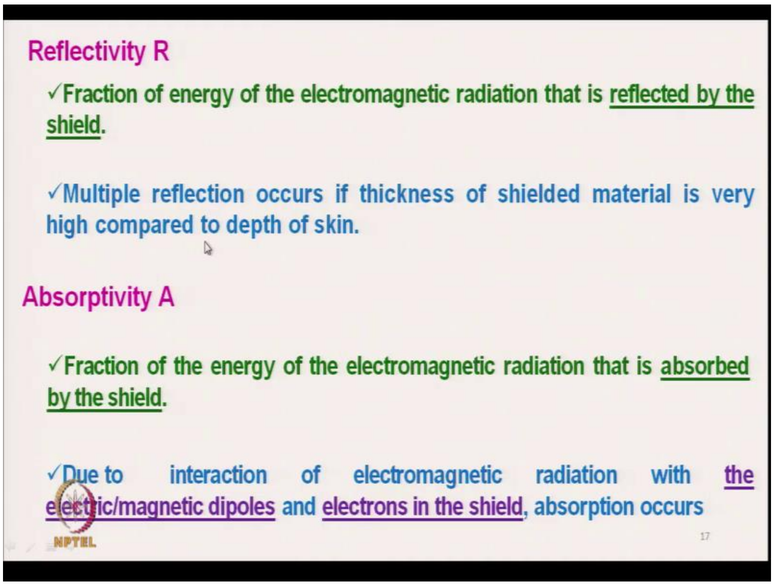

So, that the terms which we can use is one of this is reflectivity which is expressed by R, that is fraction of energy of electromagnetic radiation that is reflected by the shield material that is called reflectivity of the shield material and it may include the multiple reflection also; that is multiple reflection occurs, if thickness of the shielded material is very high compared to depth of the skin. So, there will be multiple reflection.

Next term is absorptivity which is expressed in terms of A that is a fraction of energy of electromagnetic radiation that is absorbed by the shield material. So, that we can get the absorptivity of the material so, the due to interaction of electromagnetic radiation with the electric and magnetic dipoles and electrons in the shield, the absorption occurs; so, absorptivity we can measure.

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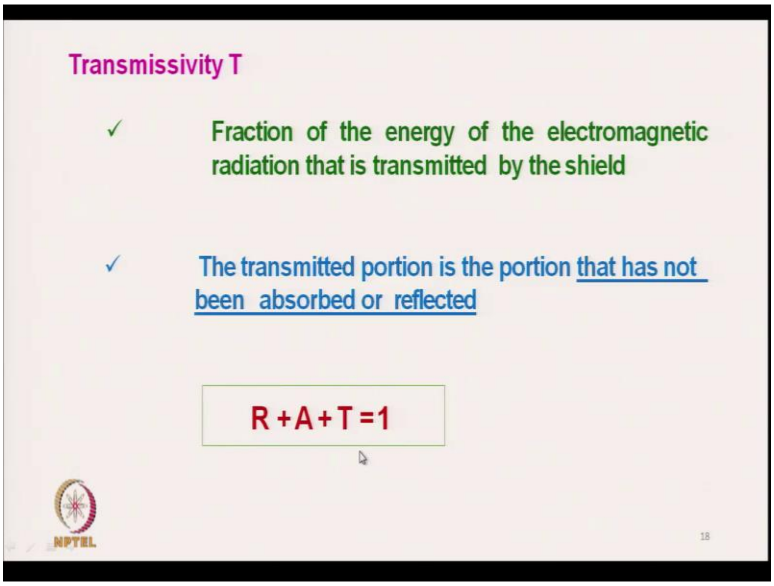

Third term is transmissivity, the transmissivity is that fraction of energy of electromagnetic radiation that is transmitted by the shield. The transmitted portion is the portion that has not been absorbed or reflected. The value of transmissivity will show the effectiveness of a shield material, a very good shield material will have least transmissivity. So, if we add all three will be unit value, R plus A plus T equal to 1. So, how to measure, you have understood the shielding mechanisms; and now we will discuss the measurement techniques. .

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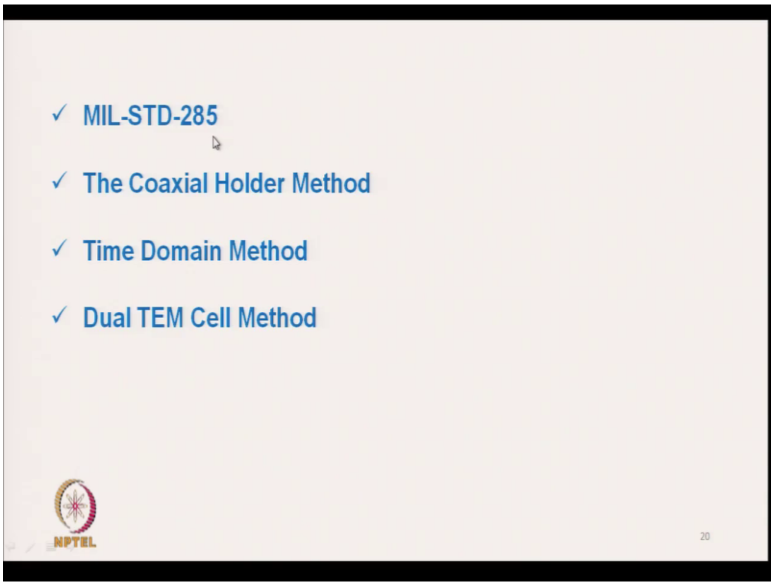

So, there are different techniques available MIL standard 285 which is military standard, we can use coaxial holder method, time domain method, dual TEM cell method; so, this methods are very commonly used.

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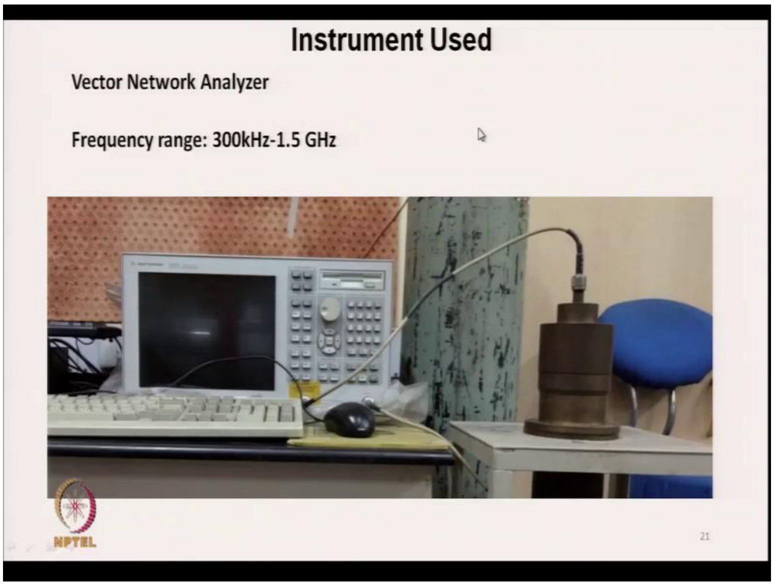

Now, the instrument which is normally used it is a vector network analyzer. This instrument is used for measuring the shielding effectiveness of textile material also it works in the frequency range of 300 kilohertz to 1.5 gigahertz.

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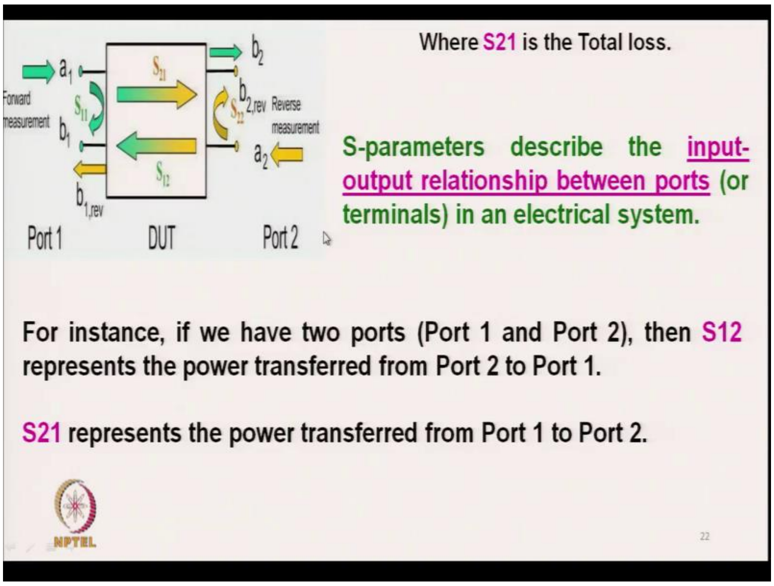

So, first let us try to understand, what is S-parameter? S-parameters describe the input-output relationship between the ports, that these are the two ports or terminals in an electrical system. So, this S-parameter, it shows the relationship between input and output ports. For example, if we have two ports; port 1 and port 2, then S12; S12 represent the power transmitted from port 2 to port 1 and S21 represent the power transmitted from port 1 to port 2.

So, if the power is coming from port 1, then S21 shows the power which is getting transmitted from port 1 to port 2 through the shielding material. So, for measurement of shielding effectiveness S21 is used.

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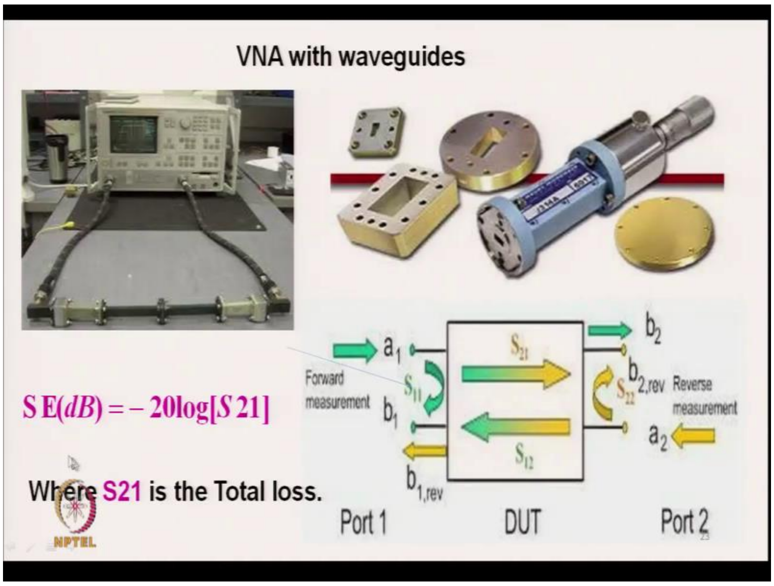

So, S21 if we take the log so, shielding effectiveness in decibel equal to minus 20 log S21, this is the common formula by which we measure the shielding effectiveness. So, S21 is total loss.

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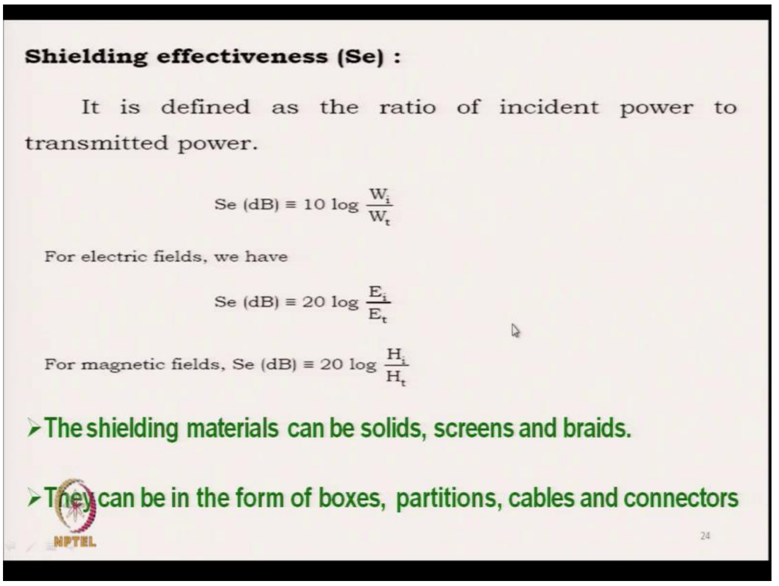

And shielding effectiveness for electrical field and magnetic field we can measure separately. So, shielding effectiveness for electrical field is minus, it is 20 log Ei by Et. So, initial and transmitted so, incidents and transmitted energy.

Similarly, for magnetic field, it is also 20 log Hi by Ht ok. The shielding effectiveness can be measured the total shielding effectiveness, it is a 10 log W incident and W transmitted ok, that is power incidence and transmitted power. The shielding material can be solid, can be screen or can be braids. And if we talk about their forms, they can be in box form, may be in partition form, may be cable form or connectors form. So, there are different forms of shielding materials.

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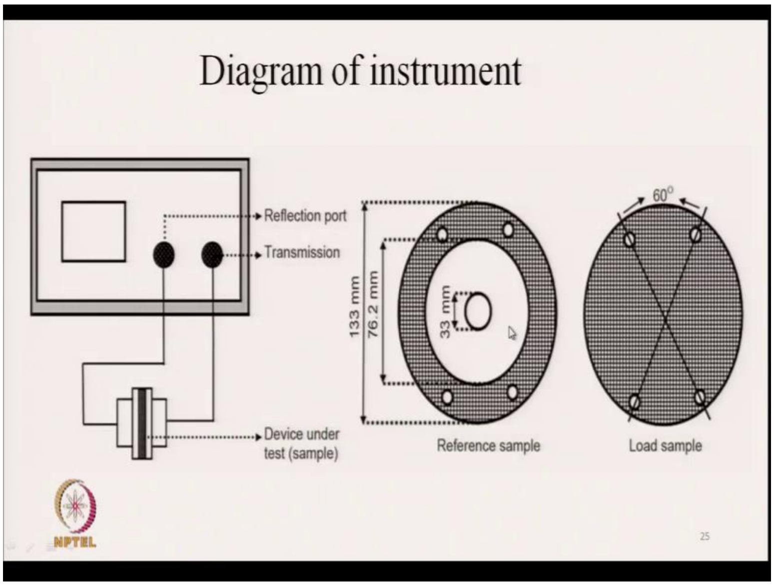

So, for measurement we have two ports, this is called a reflection port and one is transmission port ok. And here, the device which is under test, this may be a textile fabric also; and there are two types of samples, this sample annular ring and also small circular sample, this is called reference sample which we need to measure the effectiveness and another is load sample. So, if we take the difference, we will get the shielding effectiveness.

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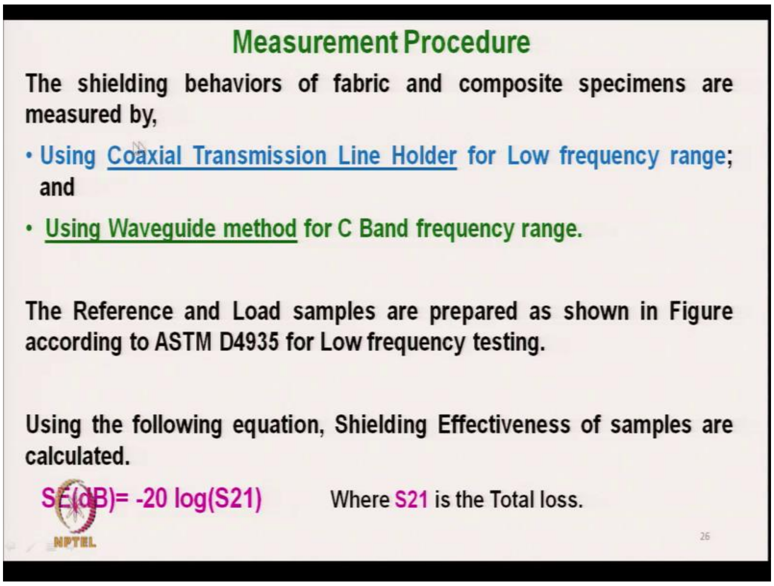

The shielding behavior of fabric and composite specimens are measured by, one is using coaxial transmission line holder which is used for low frequency range and another for C band frequency range; so, C band frequency range we can use the waveguide method. The reference and load samples as, I have just mentioned are prepared as shown in figure as per ASTM D4935 and it is used for low frequency range.

So, this formula SE equal to minus 20 log S21 is used to measure the shielding effectiveness of sample.

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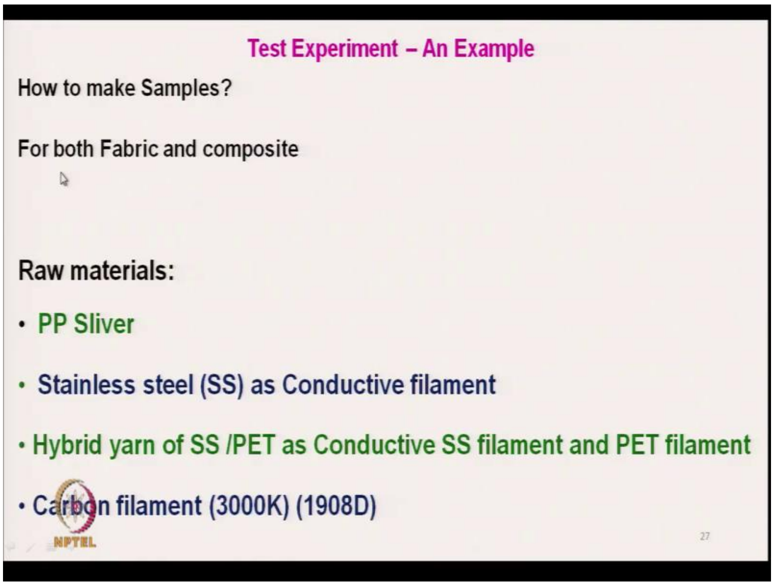

So, both textile fabrics and textile reinforced composites can be tested. The raw materials were for the experiment which has been conducted was polypropylene sliver was used, stainless steel filament which is conductive in nature, hybrid yarn stainless steel and polyester hybrid yarns were used and carbon filament was used which is conductive in nature.

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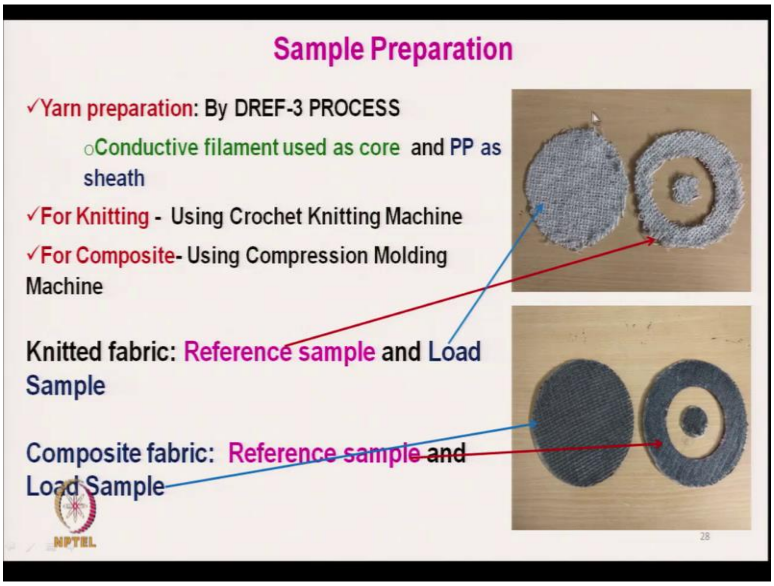

Now this is the specimen. So, two types of specimens were used, one is knitted fabric another is composite fabric; composite means, fabric reinforced composite. So, knitting was done using crochet knitting machine and composite was made using compression molding machine. So, this is load sample circular and reference sample is annular ring and also a small circular portion which is for the centre. And composite fabric was of similar shape this is for load sample, another is for reference sample.

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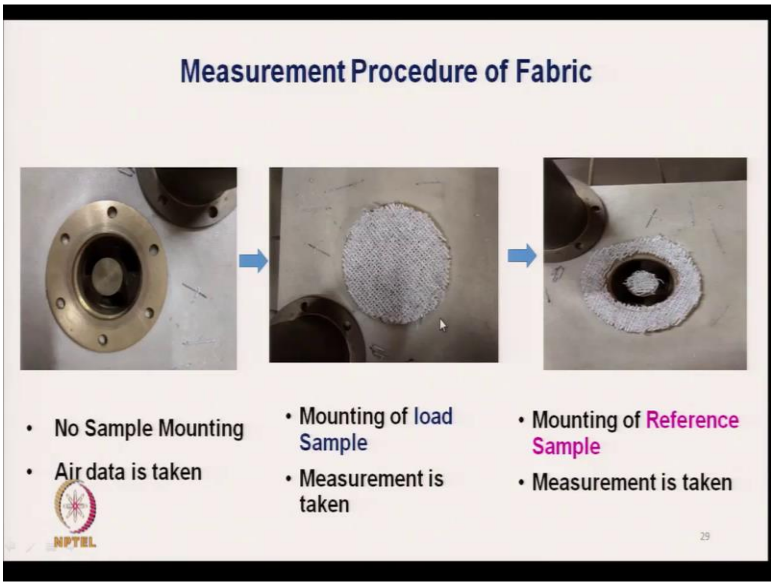

So, here the measurement procedure is, this is the basic instrument where no sample was mounted and here only air data was taken. This instrument without any sample, the electromagnetic wave passing through air was calculated for reference. Here then sample was mounted, this is the load sample was mounted and measurement was taken and third is that, reference sample was mounted on the instrument, this is the annular ring, here it was placed and at the centre the sample circular, small circular sample was placed and measurement was taken.

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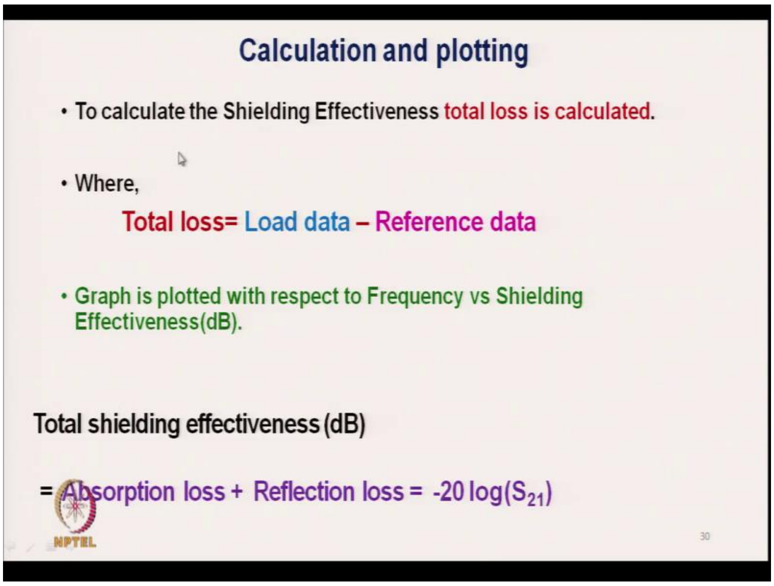

So, three readings were taken and to calculate the shielding effectiveness the total loss is calculated; so, total loss is equal to load data minus reference data. And then graphs were plotted where in x-axis the frequency was there and in y axis shielding effectiveness in decibel was reported. So, total shielding effectiveness in decibel is equal to absorption loss plus reflection loss. So, that is expressed by minus 20 log S21 so, total loss we can calculate. So, absorption loss plus reflection loss is calculated by load data minus reference data.

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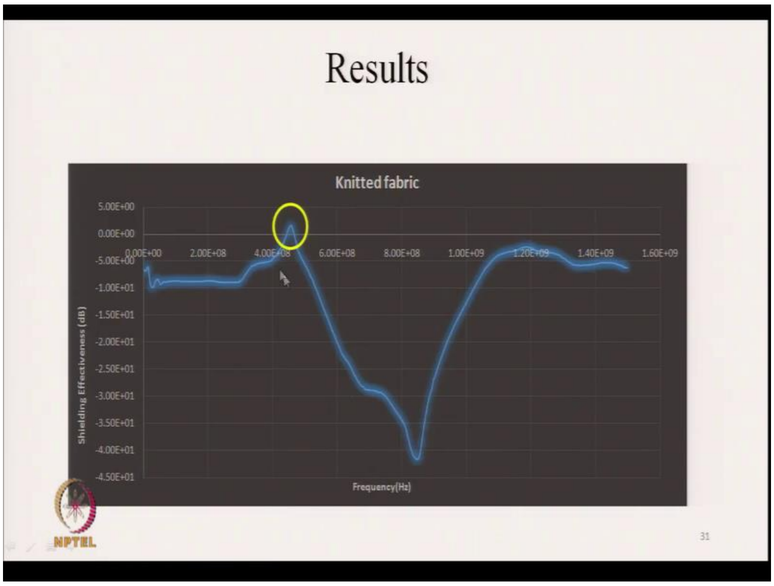

This is the typical plot where at this zone; we can see it is a maximum shielding ok.

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And this is for composite material.

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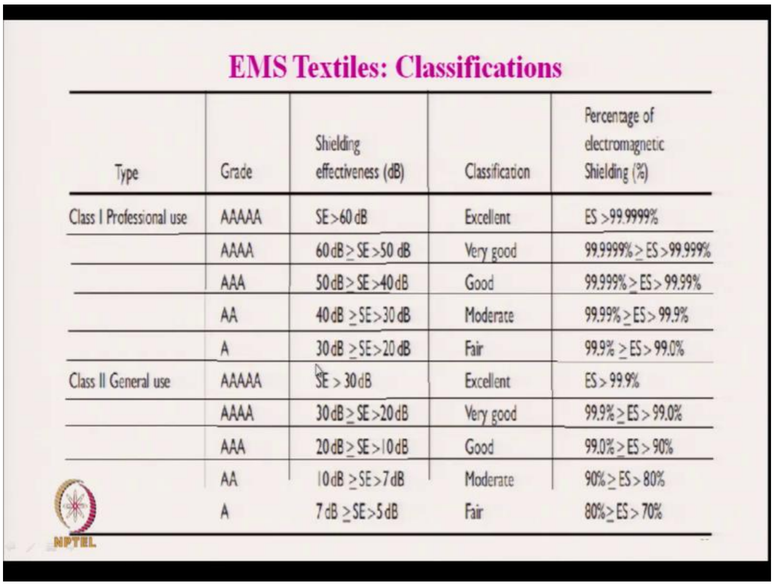

EMS Textiles: Classifications

Type	Grade	Shielding effectiveness (dB)	Classification	Percentage of electromagnetic Shielding (%)
Class I Professional use	AAAAA	SE > 60 dB	Excellent	ES > 99.9999%
	AAAA	60 dB ≥ SE > 50 dB	Very good	99.9999% ≥ ES > 99.999%
	AAA	50 dB ≥ SE > 40 dB	Good	99.999% ≥ ES > 99.99%
	AA	40 dB ≥ SE > 30 dB	Moderate	99.99% ≥ ES > 99.9%
	A	30 dB ≥ SE > 20 dB	Fair	99.9% ≥ ES > 99.0%
Class II General use	AAAAA	SE > 30 dB	Excellent	ES > 99.9%
	AAAA	30 dB ≥ SE > 20 dB	Very good	99.9% ≥ ES > 99.0%
	AAA	20 dB ≥ SE > 10 dB	Good	99.0% ≥ ES > 90%
	AA	10 dB ≥ SE > 7 dB	Moderate	90% ≥ ES > 80%
	A	7 dB ≥ SE > 5 dB	Fair	80% ≥ ES > 70%

And these are the typical data for electromagnetic shielding textile materials. There are two types of cases, case one for professional use high end technical use and case 2 is for general application. So, if we want to have high end application for excellent result for excellent, we will get the decibel which is more than 60. So, if the shielding effectiveness is more than 60, then we can call it as excellent shielding where the percentage electromagnetic wave which is being blocked which is more than 99.99 percent.

On the other hand for normal application, if the shielding effectiveness is more than 30 decibel, we can call it as excellent ok.

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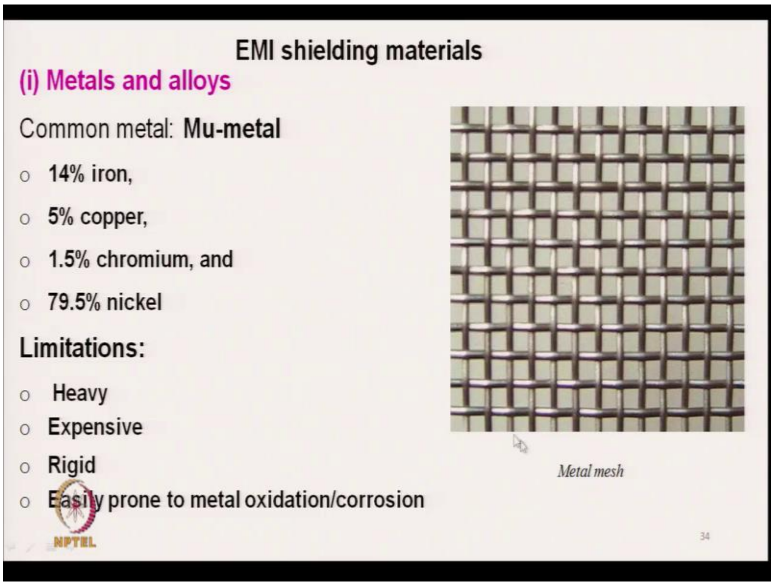

So, there are different types of materials available for shielding of electromagnetic radiation very common material is metal and alloys. So, common material is Mu metal. So, Mu metal is basically nickel, iron, alloy, but main problem with this metal is that they are heavy, expensive, rigid and it is prone to metal oxidation or corrosion. So, these are the problems, but still we can use this metals and alloys.

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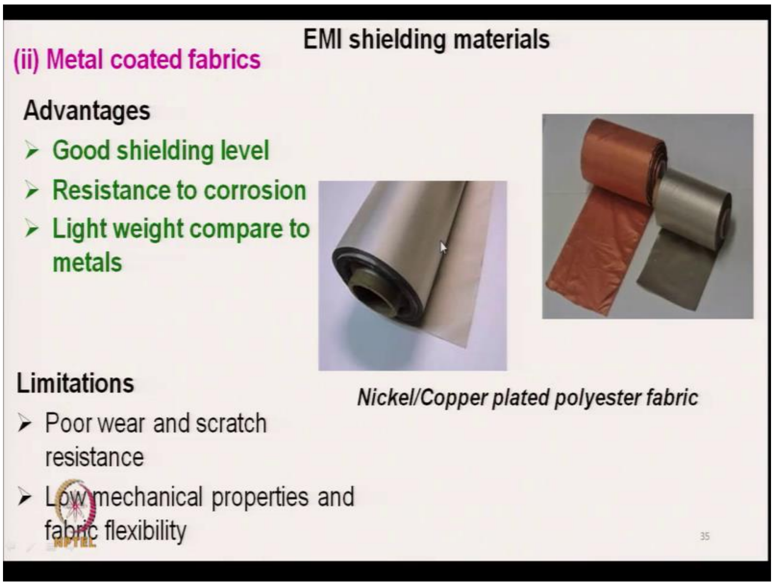

Next is that metal coated fabrics. So, they have very good shielding effectiveness, very common product is nickel, copper plated polyester fabric; so, these are the nickel copper plated fabric. So, they have high resistance to corrosion, light weight as compared to metals because only plating is there, but rest other material is polyester fabric. So, the problem of this type of material is they are poor wear and scratch resistance and low mechanical properties and fabric flexibility due to coating or plating the flexibility is reduced.

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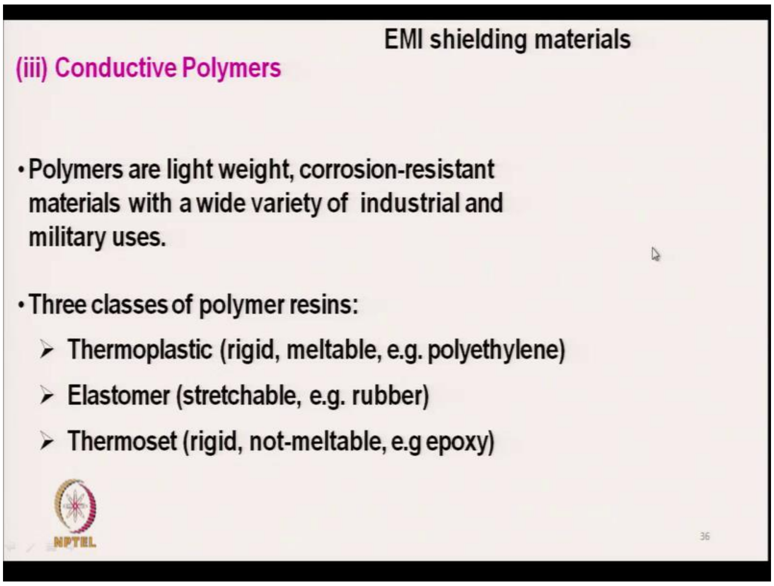

Next product is that conductive polymers. So, polymers are normally used for the lightweight corrosion resistance ok. So, they are used widely for industrial and military applications. There are different classes like thermoplastic which is meltable like polyethylene, elastomer which are stretchable material, we can use rubber, thermoset a rigid material, they are not meltable like epoxy. So, these are the normal polymers, but if we can make them conductive, this materials can be used as electromagnetic shielding material. So, these are the structure; this is the structure of conductive polymer.

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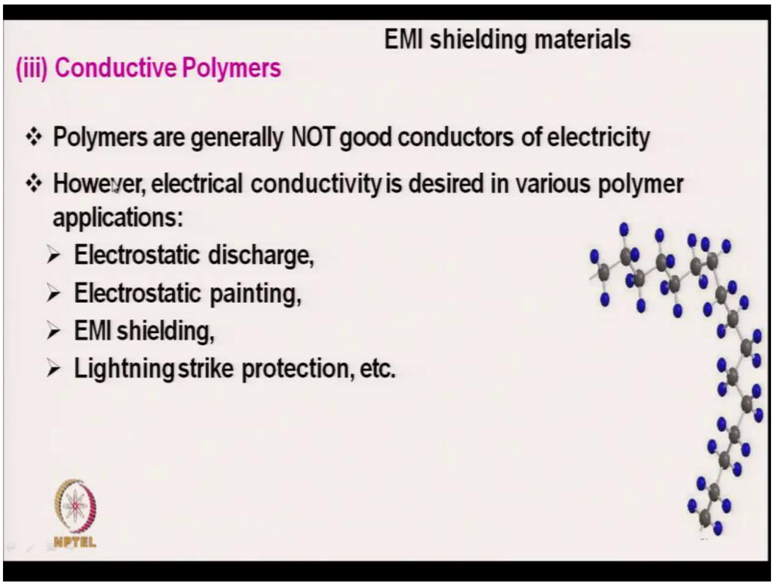

So, polymers are not good conductors; however, electrical conductivity is desired in various polymer application. So, this if we can make the polymers conductive, we can use in various applications like electromagnetic shielding ok, electrostatic discharge. So, there are different applications like lightning strike operation protection; so, we can use this material, but we have to first make the polymers conductive.

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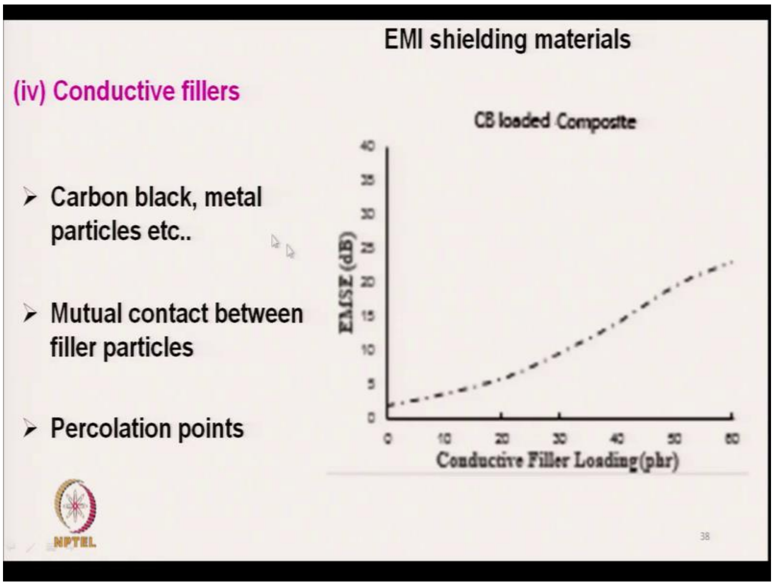

Fourth one is conductive fillers. So, like carbon black, metal particles if we can incorporate in the polymers, we can make them conductive; so, the electromagnetic shielding effectiveness increases. So, these are the in x-axis it is a conductive filler loading is shown and as the loading increases, electromagnetic shielding effectiveness increases. So, this is due to mutual contact between filler particles.

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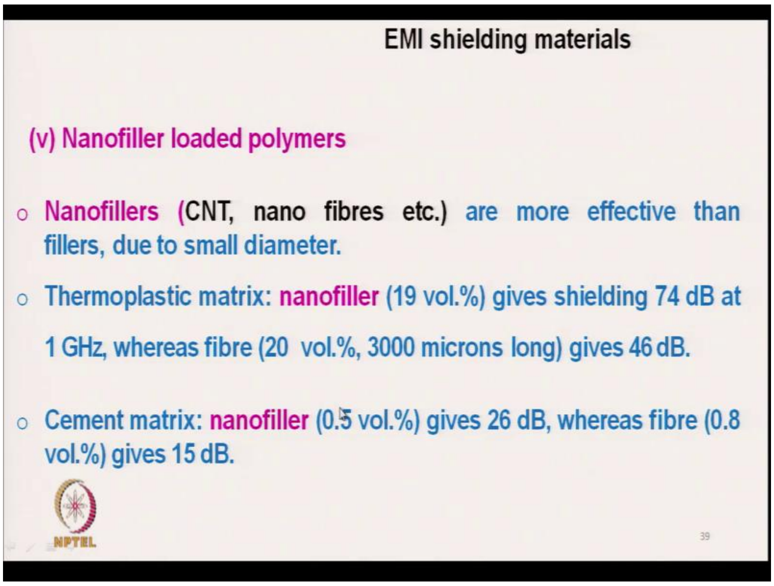

So, that those were the normal macro particles, we can have nanofiller loaded polymers also. So, nanofiller loaded polymers like carbon nanotube, nano fibres this type of particles, if we can load within the polymers, these are more effective than normal fillers due to smaller size.

So, thermoplastic matrix, if we use and if we use nanofiller within that. So, 19 percent by volume will give shielding effectiveness of 74 decibel at 1 gigahertz frequency, whereas for with 20 percent of normal micron level particle will give only 46 decibel effectiveness. Similarly, cement matrix with nanofiller 0.5 percent by volume, if we give it will give 26 decibel effectiveness and for normal fibre with even higher volume for fraction 0.8 percent volume fraction, the shielding effectiveness will be dropped to around 15 decibel. So, we can see if we use nanofiller then we can enhance the shielding effectiveness.

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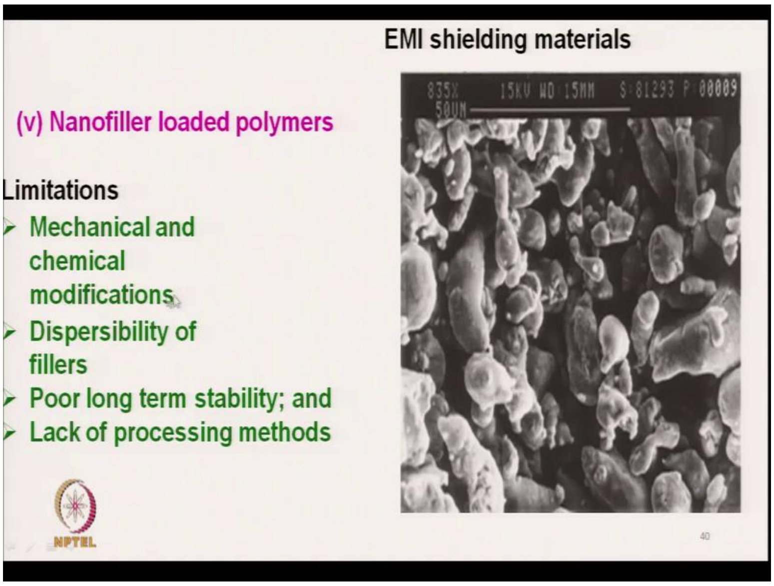

But main disadvantages of this nanofiller loaded polymers are mechanical and chemical modifications are there and dispersibility of this fillers. They are not dispersed easily, agglomeration may take place that part once you take care, poor long term stability and lack of processing methods; so, these are the problems.

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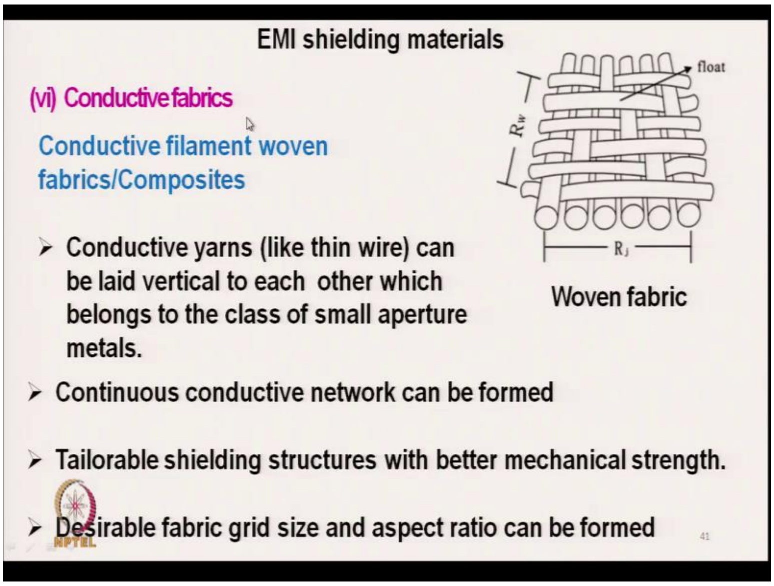

And then it is a conductive fabrics which is the best solution, because this fabrics are flexible in nature. So, conductive filament woven fabrics or composites are used, the conductive yarns like thin wire can be laid vertical to each other which belongs to the class of small aperture so, it will create small apertures.

So, continuous conductive network can be formed. So, these are the continuous conductive networks will be formed, tailorable shielding structure with better mechanical strength, we can tailor any fabric for any structure and they will have better mechanical strength, lighter weight they will be flexible, desirable fabric grids so, this grid size we can design we can actually engineer the grid size and the aspect ratio of this grids, we can create as per our requirement.

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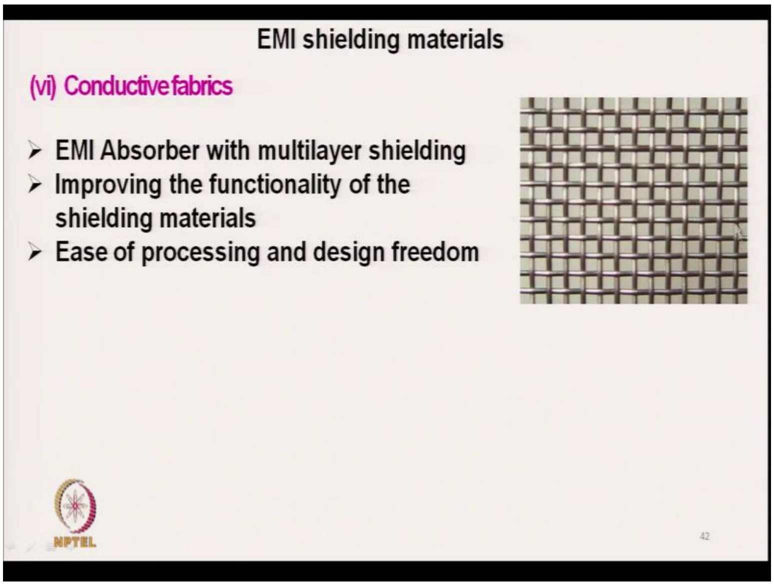

So, EMI absorber with multilayer shielding, improving the functionality of the shielding materials, ease of processing and design freedom; so, all this are the advantages of conductive fabrics.

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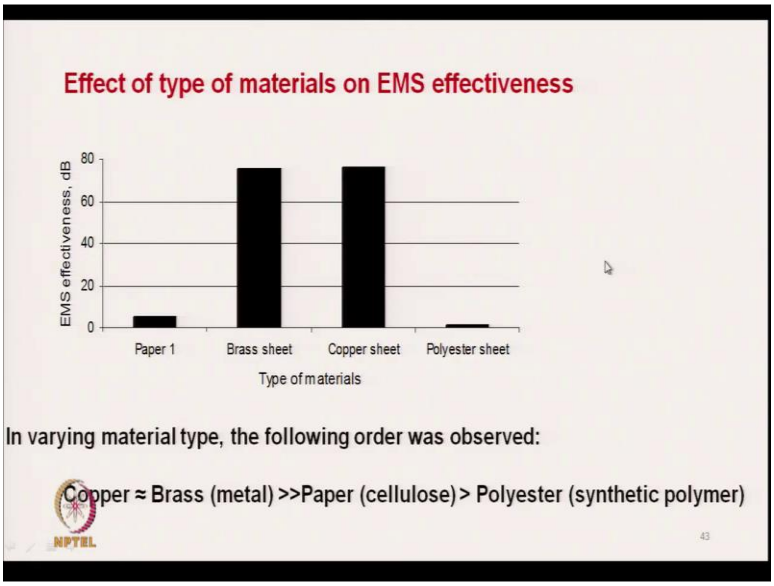

Now, we will discuss few factors which affect the electromagnetic shielding effectiveness. First if we see the type of material, here paper is used which is cellulosing material then brass sheet is used, copper sheet is used, polyester sheet is used and it is very clear that metallic sheet they are giving very high electromagnetic shielding effectiveness as compared to the cellulosic or polyester sheet ok.

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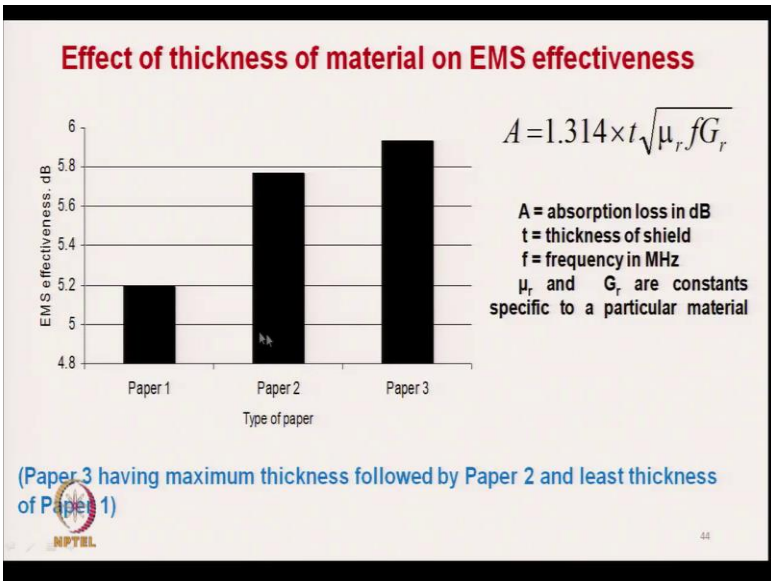

This diagram show the effect of thickness of the material. So, the paper 1, paper 2, paper 3 these are the different types of papers are being used with different GSM, Grams per

Square Meter and different thickness and paper 3 is having maximum thickness and paper 2 is having minimum thickness.

As per this equation, the absorption loss in decibel A is proportional to the thickness of the shield material, where if we keep the frequency and other parameters constant. So, as thickness increases, absorption loss also increases and here almost similar observations.

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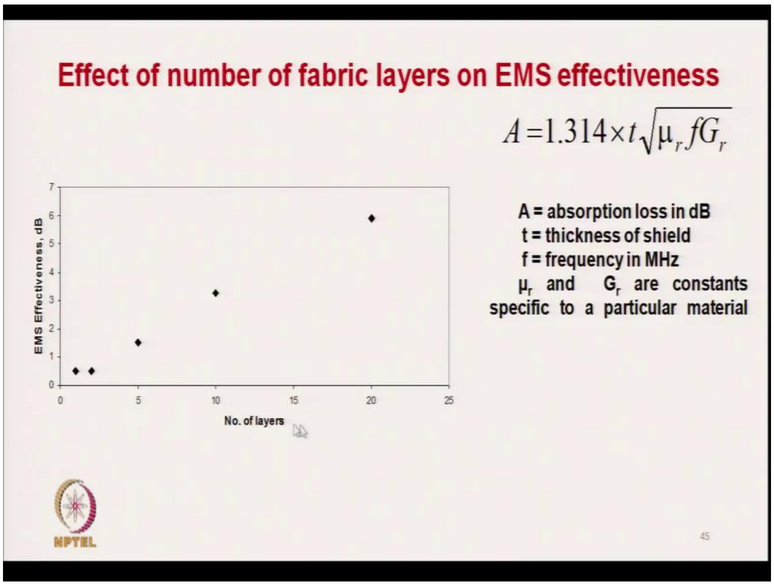

What we have done? We have increased the number of layers of fabrics. So, number of fabric layer as we increase the number of fabric layer, thickness of the layers increases so, effectiveness also increases; so, shielding effectiveness in decibel increases gradually.

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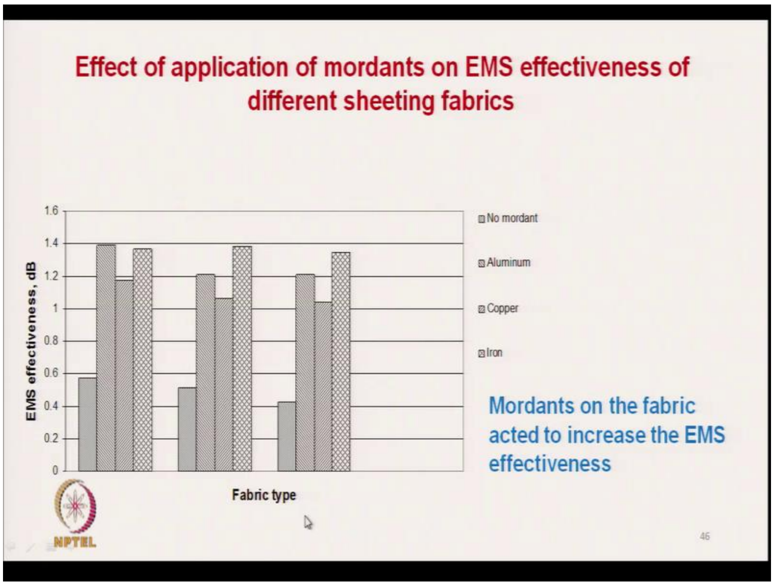

And last part we have reached here, the effect of mordant on cotton fabric has been studied. So, first portion; first bar is showing the fabric without any mordant and other bars are showing the aluminum as mordant, copper as mordant and iron as mordant. So, if we see all this graphs, the use of mordant increases the shielding effectiveness significantly, the reason being as the mordants are metallic in nature, they will enhance the conductive nature of the fabric. So, these are the few parameters.

If you want to learn more about this, there are materials available in the literature, there are standard books available, but here what we have tried? We have tried to understand basic principles of measurement of shielding effectiveness of textile materials. So, we have reached to the end of this course, hope you have enjoyed this course, we will stop here.

Thank you, thank you for your patience.