Data Communications
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Lecture # 05
Guided Transmission Media

Hello and welcome to today's lecture on guided transmission media.

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On completion of this lecture the students will be able to classify various transmission media, they we will be able to distinguish between guided and unguided media. We will be able to explain the characteristics of the popular guided transmission media such as twisted pair, coaxial cable and optical fiber. Here is the outline of the lecture. I shall give a brief introduction.

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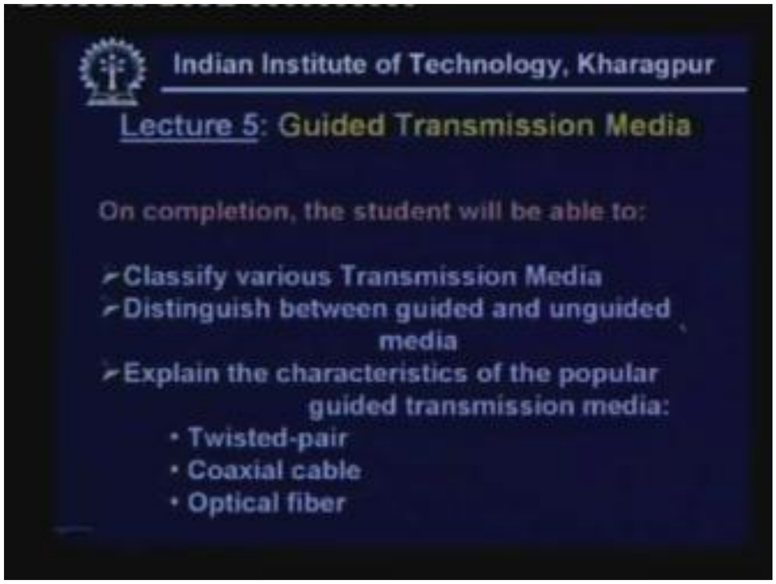

In that brief introduction I shall try to explain the need for studying the guided transmission media. Then we shall discuss about the transmission media classes, we shall consider different classes of transmission media and we shall study in detail the characteristics and applications of twisted pair cable, coaxial cable and optical fiber cable. These are the three guided transmission media which will be studied in this lecture.

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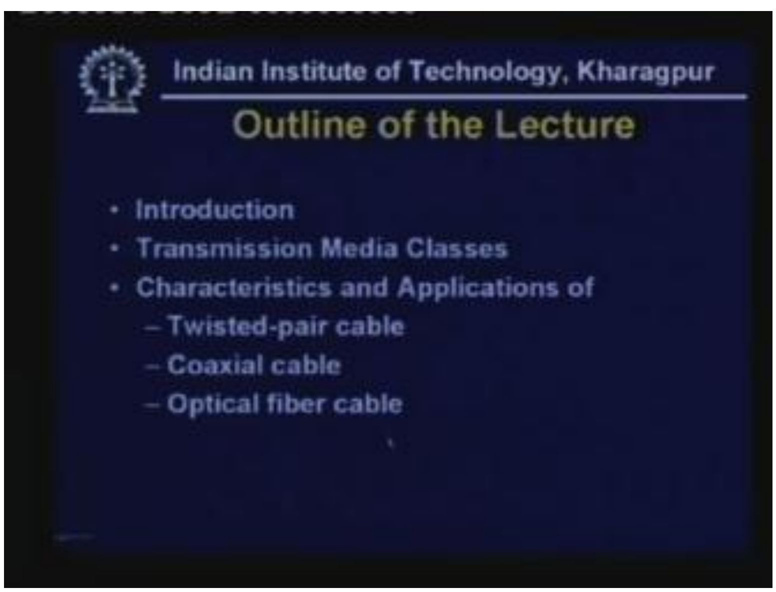

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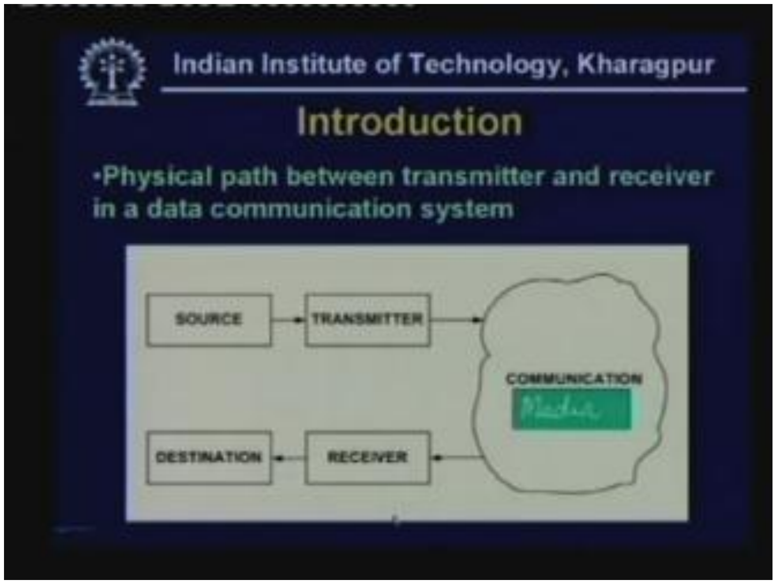

First let us look back. As you know the transmission media or communication media actually between the transmitter and receiver provides the physical path. So here you have got the transmitter and here you have got the receiver and in between you have got the transmission media and the entire thing this part is the complete data communication system. So communication media is very important for communication between source and destination.

In one of the earlier lectures we have seen the Shannon Hartley theorem that provides the channel capacity limit based on bandwidth. Here this parameter B is the bandwidth of the medium and m is the number of levels with which you are encoding the signal. So we see that the capacity of the channel or the information rate at which the data can be communicated depends on the bandwidth of the channel. Hence the bandwidth of the channel plays a very important role.

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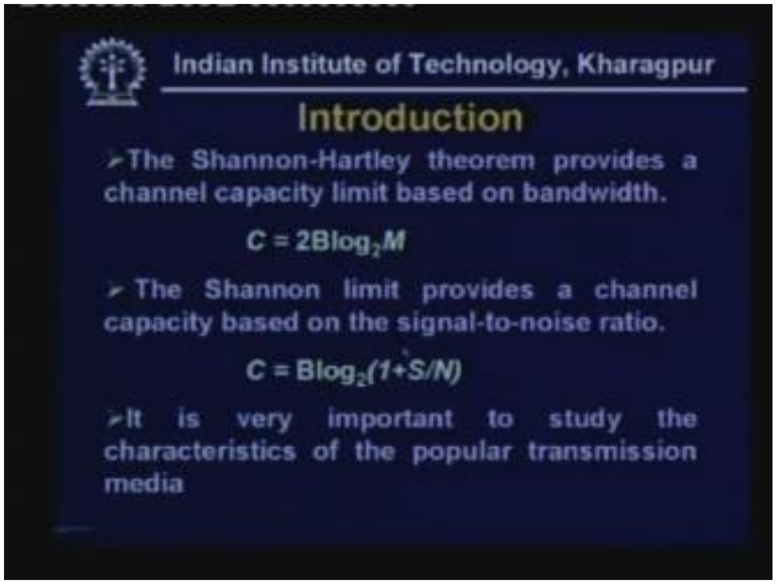

Similarly, if we look at another important equation that gives the Shannon limit that provides a channel capacity based on the signal to noise ratio. So here we see that this gives the upper limit for information exchange which is given by Blog2 (1 plus S by N) so signal ratio plays a very important role. So signal ratio of the medium has to be studied and we have to understand the different media characteristics with respect to signal to noise ratio. This gives us the need for studying transmission media and particularly it is very important to study the characteristics of the popular transmission media which we shall do in this lecture.

First let us look at the classification. The transmission media can be broadly classified into two types. In the first case we call it guided transmission media where waves are guided along a solid medium such as copper, twisted pair, copper coaxial cable or optical fiber. So we have got three examples for the guided media. One is copper twisted pair, second one is copper coaxial cable and third one is optical fiber.

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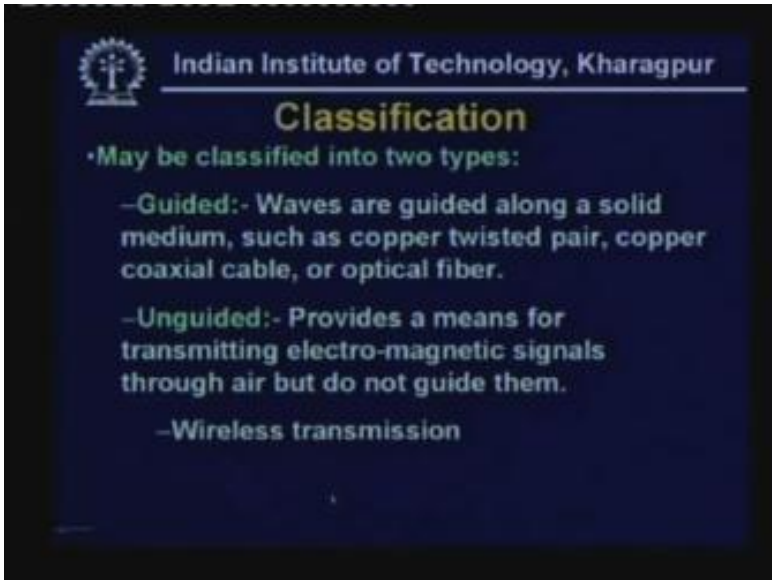

So far as the unguided media is concerned it provides a means for transmitting electromagnetic signals through air but do not guide them. So in such a case we are communicating though air and obviously whenever we communicate through air then we have to choose proper antenna and so on and this unguided transmission is called wireless transmission. And you can see here the various classifications as I have already explained. There are two basic categories; one is guided and another is unguided.

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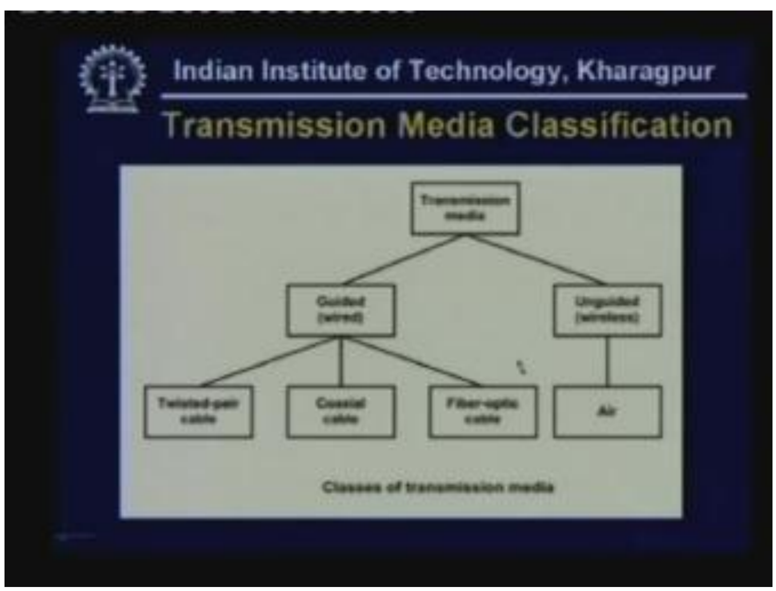

Under guided which may be called wired we have got twisted pair cable, coaxial cable and optical fiber. And on the other hand in case of unguided wireless communication it is air. But it may not be necessarily air it can be water, it can be free space but primarily we shall be concerned with air because most of our data communication will take place through air. Now let us look at the quality of transmission.

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As you send signal though a transmission media the quality of signal will be dependent on some parameters. What are the parameters on which the quality of transmission will depend? Let us see how it depends in case of guided media.

Characteristics and quality of data transmission are determined by medium and signal characteristics. Now let us consider guided media. In case of guided media the medium is more important in determining the limitations of transmission. That means the quality of transmission will be primarily determined by the transmission media. As we have already seen it is the bandwidth of the medium, the signal to noise ratio and also the attenuation characteristics of the medium. So these parameters will be very important in case of guided media.

On the other hand in case of unguided media the bandwidth of the signal produced by the transmitting antenna is more important than the medium. So when we transmit by using unguided media the frequency spectrum that is transmitted by the antenna will play more important role than the medium itself. In other words we can use same medium to transmit signals of different frequencies using antennas of different shapes and sizes as we shall see. So in that case the antenna will play the key role in deciding the transmission characteristics. These are the two broad situations. Now let us focus on the guided media

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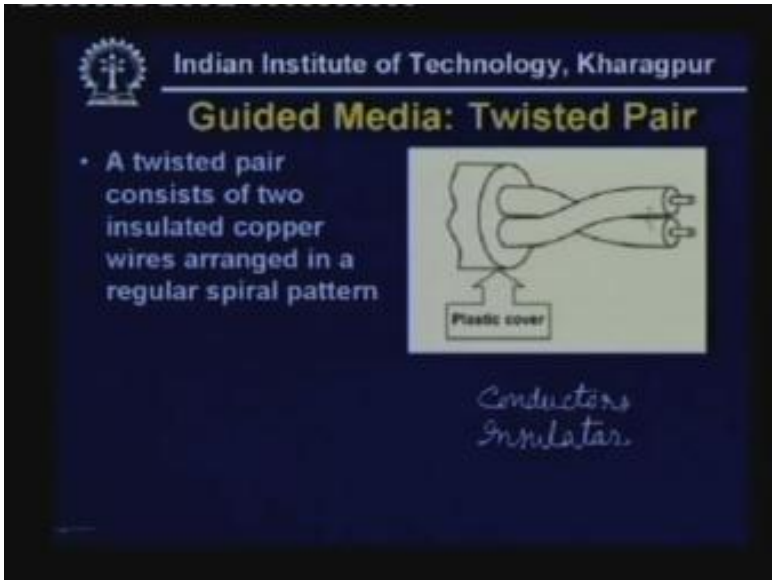

First we shall consider the twisted pair cable. A twisted pair cable consists of two insulated copper wires arranged in a regular spiral pattern. As you see in this diagram this is one conductor and this is another conductor so you have two conductors. And this is insulated here is your insulator (Refer Slide Time: 8:50) and then there is a plastic cover in which both the cables are put in the twisted form. As you can see there is some kind of helical form in which the wires are twisted.

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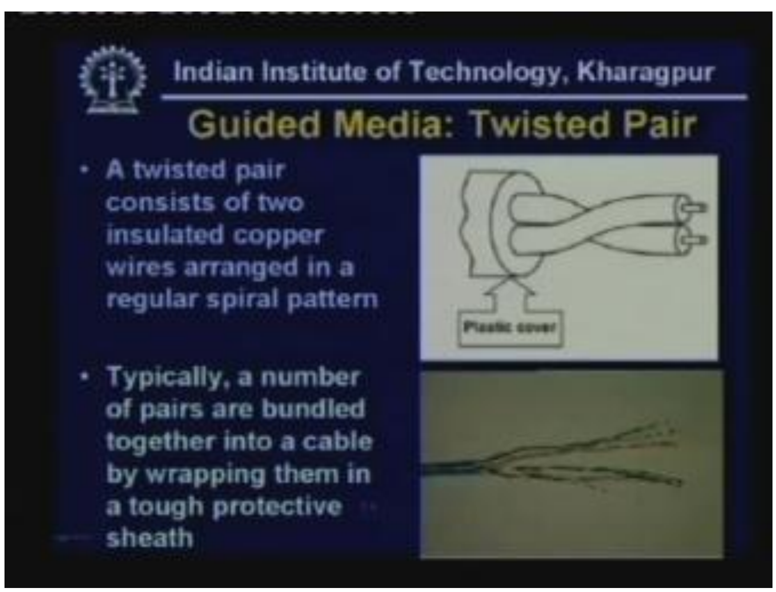

Now typically you are not using just one pair of wire. Typically a number of pairs are bundled together into a cable by wrapping them in a tough protective sheath. In this diagram as you can see (Refer Slide Time: 9:23) we have got several twisted pairs, here this is one twisted pair, this is another twisted pair, this is another twisted pair so a large number of twisted pairs are wrapped with the help of a tough protective sheath and that is actually used for data communication. So from one building to another building, from one place to another place with large number of twisted pair of cables a single protective sheath is used. That will create some problem as we shall see later.

Now you may be asking what is the need for twisting, why we are twisting the wires, why not just put two wires as it is, what is the need for twisting. The need for twisting arises because of a phenomenon called crosstalk.

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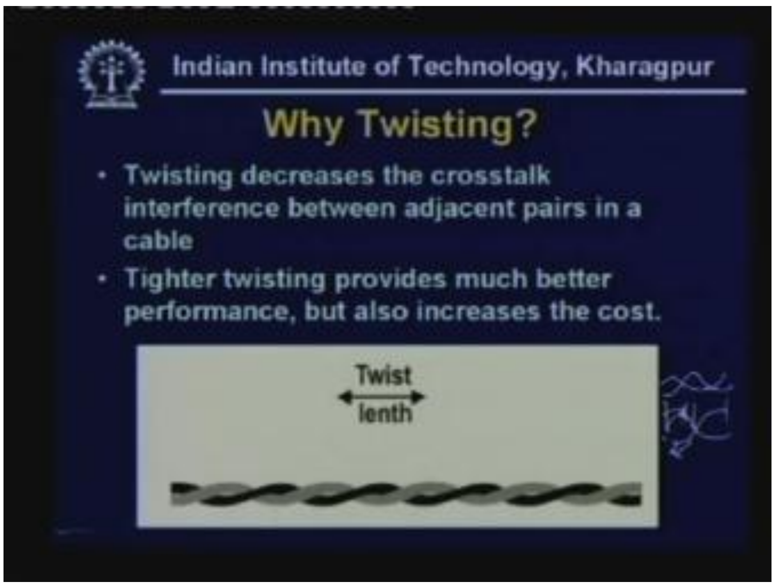

As we have seen in the previous slide we are taking not just one twisted pair but a large number of twisted pairs together. Thus signal passing in one pair of wire will induce signal in another pair of wire. So in our somewhat experience of telephone system we know that whenever we are talking in the background if you listen carefully you can here some conversation and that conversation we normally call as crosstalk. The crosstalk is arising because the adjacent pairs are inducing some signal in the twisted pair of wire while the conversation is on between both speakers.

Now how it reduces the crosstalk?

Actually as you can see here this is one wire and this is another wire (Refer Slide Time: 11:24) so current is flowing in one direction in one way and it is flowing in the reverse direction in another way. And if they are twisted together actually the field induced by this wire will be just opposite to the field induced by the other wire that means they will cancel out each other. Similarly if there is an adjacent pair here which is actually acting as some kind of transmitter then it will induce on this part, it will also induce on this part and since they are in opposite directions they will cancel out. So what is happening in this case is the twisting is actually canceling out the interferences between adjacent pairs of wires. In other words it is minimizing crosstalk.

Now you may be asking that whether the number of twist per inch play any role? That means number of twist per some length say per inch or per feet whatever it may be does it play an important role? Yes, actually tighter twisting provides much better performance but also it increases the cost.

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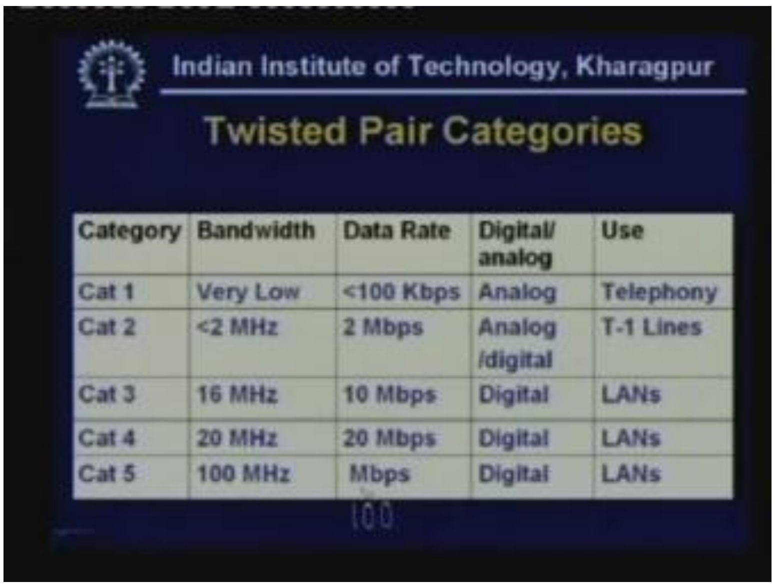

Category	Bandwidth	Data Rate	Digital/ analog	Use
Cat 1	Very Low	<100 Kbps	Analog	Telephony
Cat 2	<2 MHz	2 Mbps	Analog /digital	T-1 Lines
Cat 3	16 MHz	10 Mbps	Digital	LANs
Cat 4	20 MHz	20 Mbps	Digital	LANs
Cat 5	100 MHz	Mbps	Digital	LANs

For example, here we can see that we have got several categories of twisted pair of wire. Here we see Cat 1, Cat 2, Cat 3, Cat 4, Cat 5 these are essentially categories of wires.

Cat 1 cable has got very low bandwidth and we can send data at the rate of about 100 Kbps it is commonly used for analog transmission and primarily used in telephone systems telephone networks.

Cat 2 cable has got a lower bandwidth less than 2 MHz and you can use data rate of up to 2 Mbps. It can be used for analog transmission as well as for low bandwidth digital signal transmission. For example in telephone lines T-1 lines it is used. Later on we shall discuss about these T-1 lines in more detail.

Then Cat 3 which has a bandwidth of 16 MHz allows data rates of 10 Mbps and this can be used not only for analog data communication but it is also commonly used for digital data communication. Particularly it is used in Local Area Networks as we shall see later.

Category 5 has got 20 MHz bandwidth with data rate of 20 Mbps. It is also primarily used in digital data transmission, digital signal transmission and commonly used in Local Area Networks.

Then we have got Category 5 having bandwidth of 100 MHz and here actually there will be 100 Mbps (Refer Slide Time: 14:35) and it also uses digital data transmission particularly in Local Area Networks. Category 6 and category 7 are also available nowadays but I have not given it here but just I have given Cat 1 to Cat 5. And the two commonly used categories are Cat 3 and Cat 5 as we have already seen.

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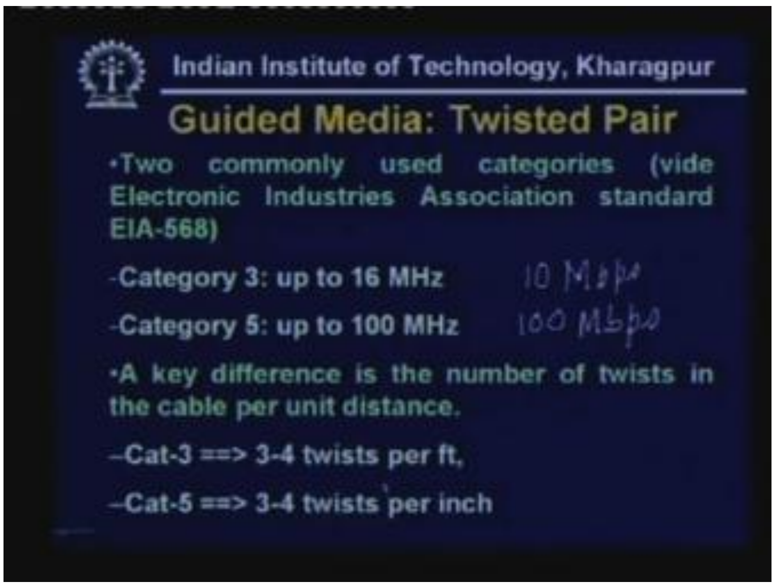

Category 3 has a bandwidth of 16 MHz and it is commonly used in for data transmission at the rate of 10 Mbps and category 5 has got bandwidth of 100 MHz so you can use it for hundred Mbps. And obviously the key difference between the two is the number of twist in the cable per unit distance.

As we can see in case of category 3 the number of twists per feet is 3-4 that means 3-4 twists per feet. On the other hand for category five it is three to four twist per inch so we can say the number of twists in category 5 is about twelve times that of category 3 because it is per feet and here it is per inch. Therefore by increasing the number of twists we are able to improve the performance. However, as you increase the number of twists the cost also increases as we have already mentioned.

Now the twisted pair of wire is available in two different types. One is know as unshielded twisted pair and another is shielded twisted pair. Let us look at the difference.

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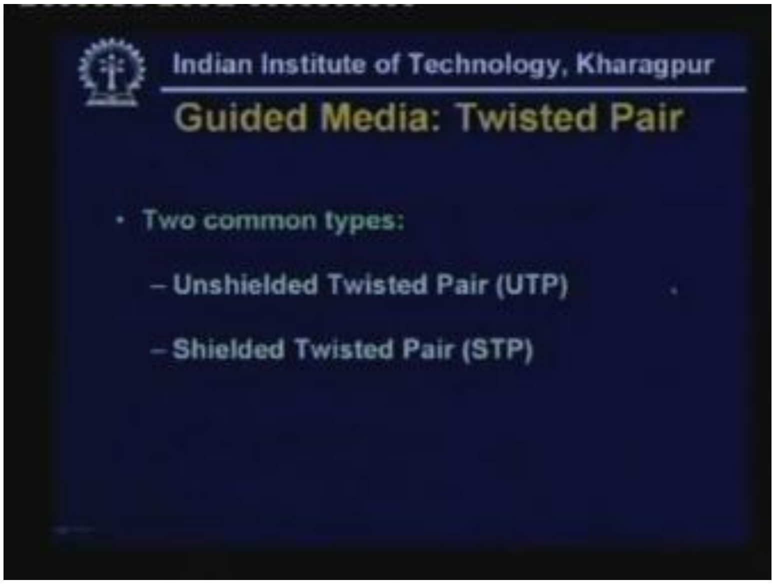

As we have already seen in case of unshielded twisted pair apart from these two conductors and insulators there is a protective plastic cover, there is no other conductor or shielding.

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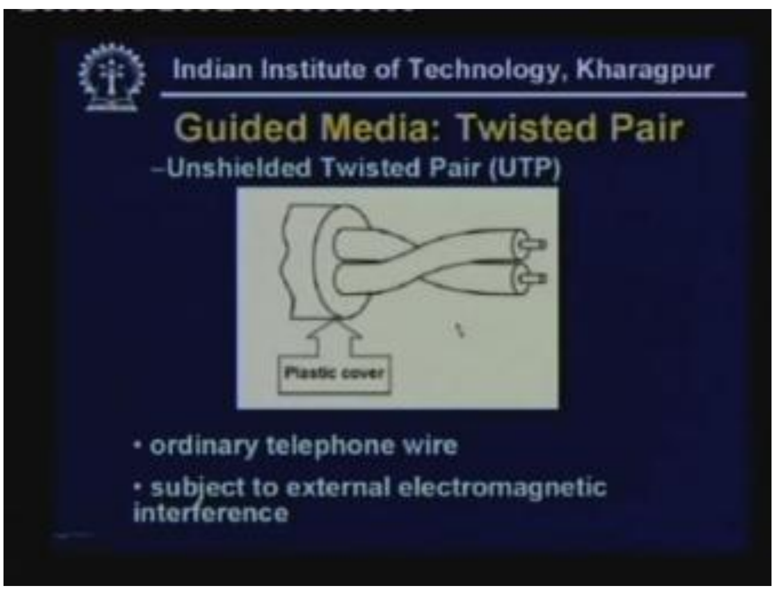

Now this is sufficient for ordinary telephone wire telephone network but however as there is no protective shield it is subjected to external electromagnetic interference. That means whenever this twisted pair of wire is taken through some industrial environment where lots of sparks and other things are going on then it creates a problem. So it is induced and that's why whenever lightning occurs or there is some spark or a car is moving close by that signal is induced in this unshielded twisted pair of wire. However, this can be reduced by using shielded twisted pair where as you can see we have got an additional conductor in the form of braided mesh.

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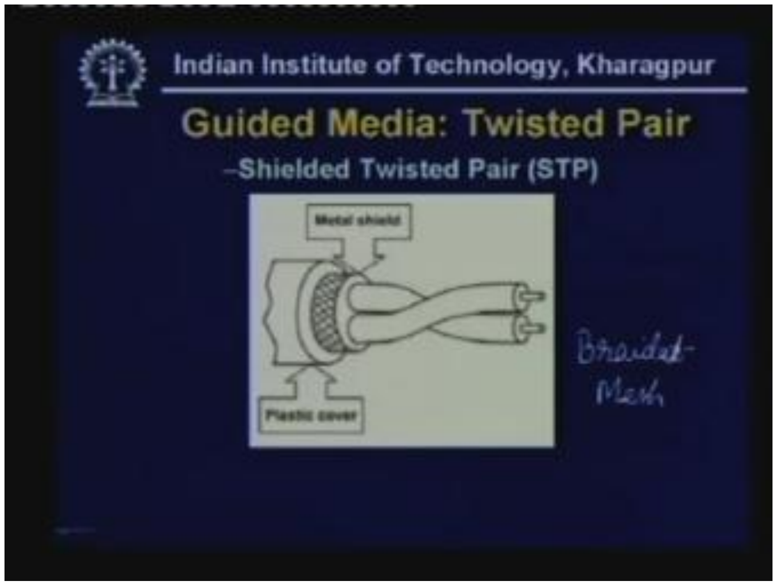

It is not a solid conductor but it is available in the form of braided mesh and this metal shield can be connected to the ground and after that there is a plastic cover. That means if this particular shield is connected to ground then this particular metal shield will rotate both the wires from electromagnetic interference. So whenever we want lesser electromagnetic interference we should use shielded twisted pair. However, shielded twisted pair is definitely costlier than the unshielded twisted pair. Thus shielded twisted pairs are not that popular in our day to day common applications in telephone networks as well as in Local Area Networks therefore usually UTP or Unshielded Twisted Pair of cables are used.

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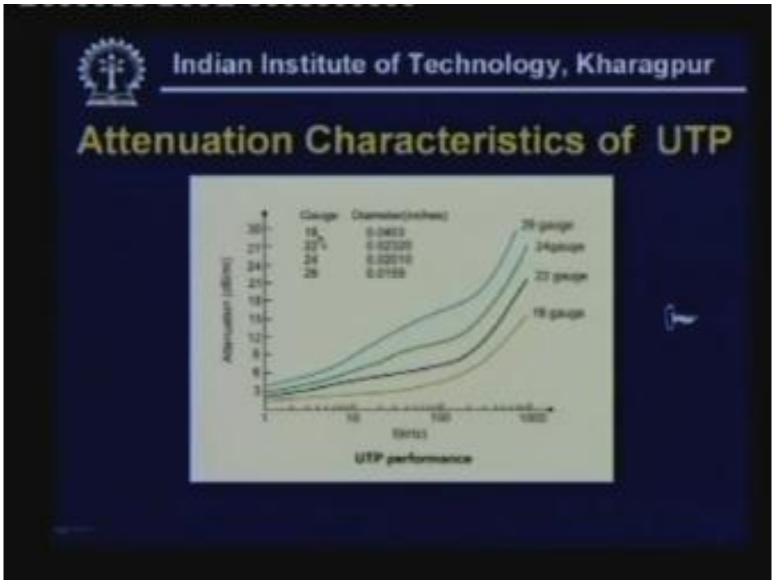

Here are the attenuation characteristics of different types of UTP cables. Here you see that in the inner conductor that is used there is an insulator. This inner conductor diameter is specified here 18 gauge, 22 gauge, 24 gauge and twenty six gauge and here the diameters are given in inches 18 gauge corresponds to 0.0403 inch.

On the other hand 26 gauge has diameter 0.0159 gauge. So it is quite obvious that higher the diameter of the conductor lesser will be the attenuation. So 18 gauge wire gives you lesser attenuation compared to 26 gauge and obviously the 18 gauge wire will be costlier than 26 gauge. These are the common wire diameters and the gauge of wire given here and as we can see attenuation is given in dB per meter and here is the frequency. So at higher frequencies the attenuation increases for UTP.

Apart from increase in attenuation at higher frequencies as the length of the wire increases the attenuation also increases. It has been found that the attenuation is proportional to 1 by distance square so attenuation is proportional to proportional to distance square. Therefore as distance increases the attenuation becomes more and in such a situation as you know we can use repeater to amplify the signal and regenerate it and resend it if necessary. The twisted pair UTP is the simplest and possibly the cheapest guided media used in many application.

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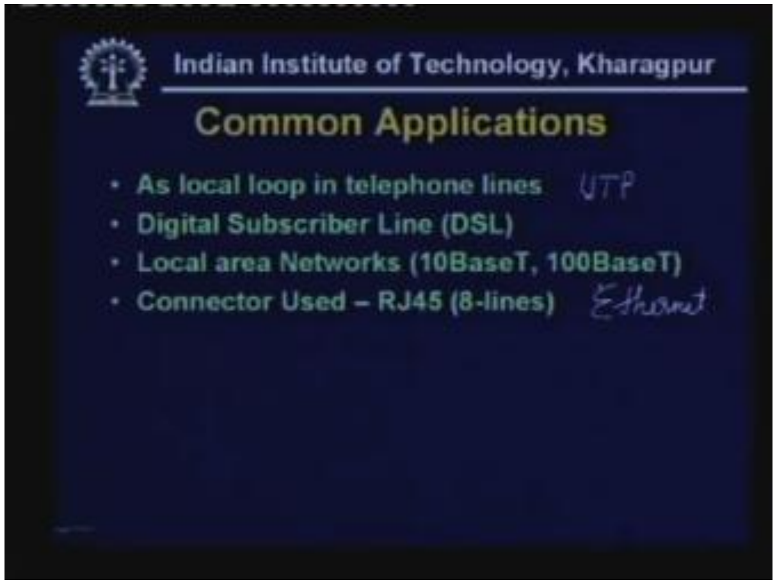

One of the most common application is local loop in telephone lines. That means in a telephone network the connection that you are getting to your home from the local exchange the wire that is used is your UTP and it is also used in Digital Subscriber Line DSL. Nowadays DSL is becoming more popular. We shall discuss about it in more detail. In DSL also the UTP is used.

Later on we shall as we shall discuss the Local Area Networks there also the twisted pair of wire is used UTP category five or category six cables are used in different situations for point to point communication particularly 10BaseT and 100BaseT Ethernet network. Later on we shall discuss about it in more detail. Normally the connecter used is RJ45 with eight lines. This is the type of connector that is used in the context of UTP cables.

Now we come to the second type of guided media that is your coaxial cable.

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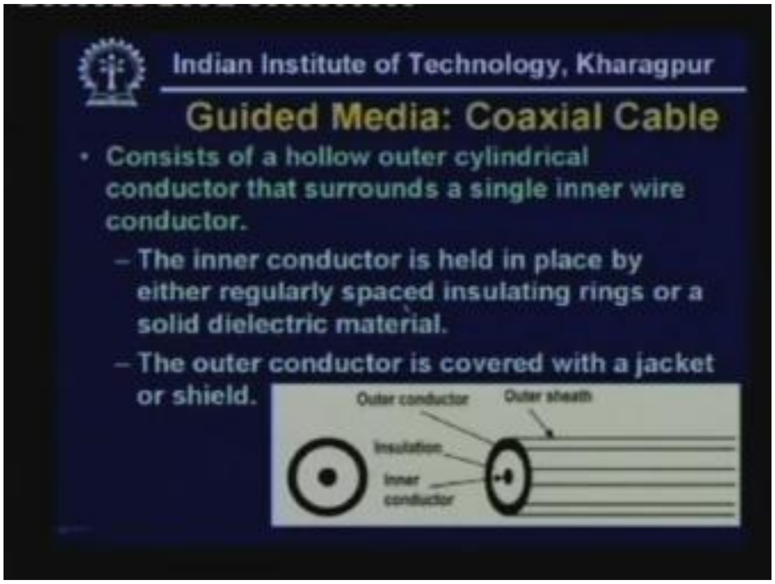

Coaxial cable consists of a hollow outer cylinder. As we can see there is a hollow outer cylinder this is the hollow outer cylinder (Refer Slide Time: 22:35) that surrounds a single inner conductor. This is the inner conductor which is held in place by either regularly spaced insulating rings where you have got solid dielectric material inside. So this is the cross sectional view of the coaxial cable and here as you can see this is the inner conductor then you have got the insulator and there you have got the outer conductor then there is an outer protective shield.

Hence that forms the coaxial cable and there is an outer jacket made of plastic that is used to cover that outer conductor. So we have got two conductors where one is the insulator and the other is a protective shield.

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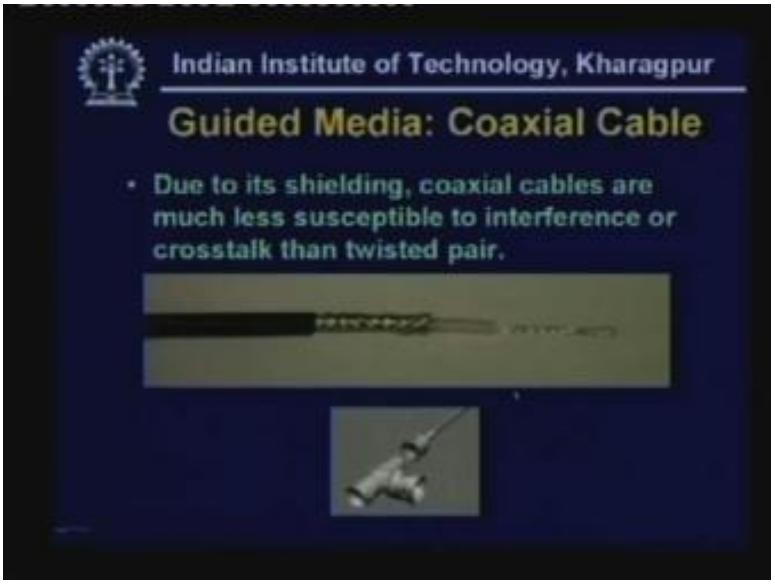

So here you can see a real coaxial cable. Here is the inner conductor which is solid and here is the insulator then the outer conductor and here is the protective shield. These are the four components; outer protective shield, outer conductor, inner insulator and the inner conductor. And because of the shielding coaxial cables are much less susceptible to interference or crosstalk than twisted pair. So what possibly can be done is the outer conductor can be grounded and then as the outer conductor is grounded the inner conductor is shielded from interferences and disturbances and that helps to reduce the crosstalk. The crosstalk in case of twisted coaxial cable is much less than twisted pair of wire. Normally the BNC connectors are used in connection with coaxial cables.

So here is the coaxial cable and here is the connector (Refer Slide Time: 24:47) then this is the BNC T connector and other side can be connected to another cable. This is how the connection is done.

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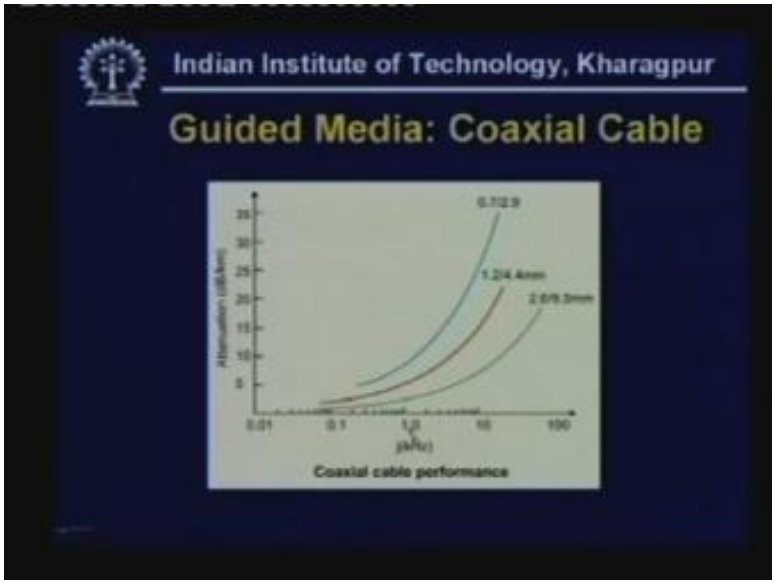

Here is the performance of the coaxial cable. Here as we can see on this side we have got the attenuation, decibel dB is in kilometer, here it is in kilometer, here is the frequency f in KHz. So here you see the frequency ranges from .01 KHz to 100 KHz and here you have got three different types of cables with inner and these two are representing diameter of the inner conductor and diameter of the outer conductor. So obviously here the diameter is less .07mm and outer conductor diameter is 2.9mm and in this case it is 1.2 inner conductor diameter and 4.4mm outer conductor diameter and the other one is 2.6mm diameter of the inner conductor and here 9.5mm is the diameter of the outer conductor. And obviously this will have lesser attenuation than the other two.

In case of coaxial cable the twisted pair of wire provides you higher bandwidth than the twisted pair of cable. This coaxial cable is used in a variety of applications in television distribution, for cable TV applications, the television signal that is coming to your house from cable TV uses coaxial cable.

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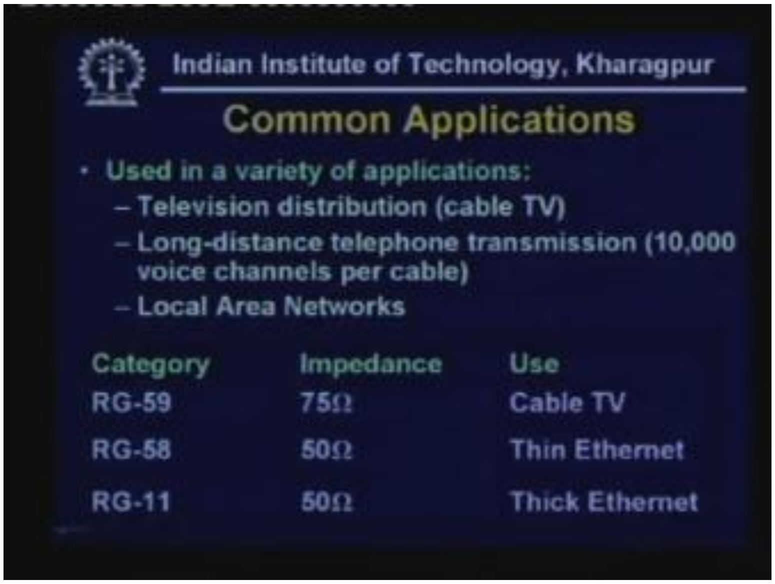

And as you know a number of channels are coming through the same cable that means bandwidth is high. That's why it is possible to send several channels by using frequency division multiplexing with the help of coaxial cable. So you can transmit several frequency bands using the coaxial cable because of higher bandwidth. It is also used for long distance telephone transmission and because of higher bandwidth it is possible to send ten thousand voice channels per cable. In a single cable we can send ten thousand voice channel simultaneously and that is possible because of higher bandwidth. It is also used in Local Area Network. As we can see here three categories of coaxial cables are given here RG-59, RG-58 and RG-11 with characteristic impedance of 75 ohm, 50 ohm and 50 ohm.

This RG-59 is commonly used in cable TV which is very popular and is of low cost. Then RG-58 with characteristic impedance of 50 ohms that means the cables are to be transmitted are to be terminated by 50 ohms resistance and that is used in thin Ethernet which gives a data rate of 10 Mbps. RG eleven is thick Ethernet with characteristic impedance fifty ohms also used in thick Ethernet

So RG-11, eleven RG-58 and RG-59 these are the three popular coaxial cables commonly used in three different applications. Later on when we discuss about Local Area Networks particularly the Ethernet. We shall discuss about thin Ethernet and thick Ethernet and the use of two different coaxial cables in Ethernet technology. Now let us look at the third guided media which is your optical fiber.

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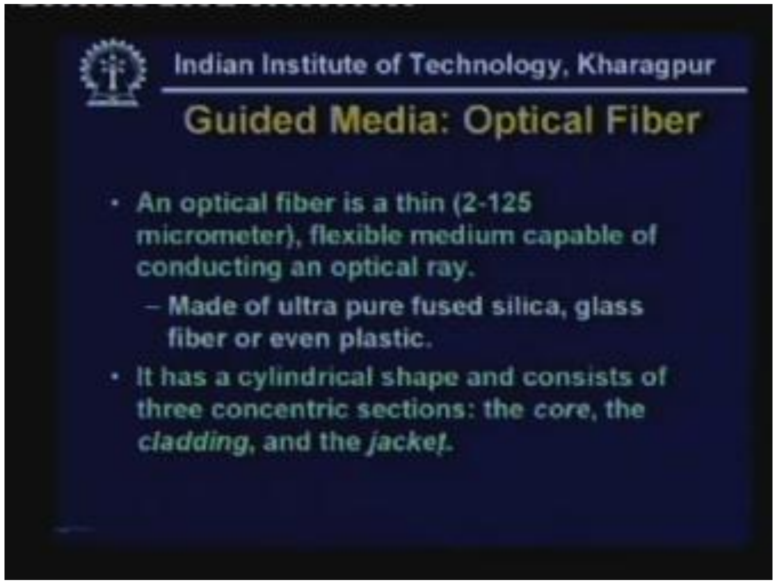

An optical fiber is a thin flexible medium capable of conducting an optical ray. It is made of ultra pure fused silica glass fiber or even plastic and it has a cylindrical shape and consists of three concentric sections the core, the cladding and the jacket. Let us see the structure of the optical fiber cable.

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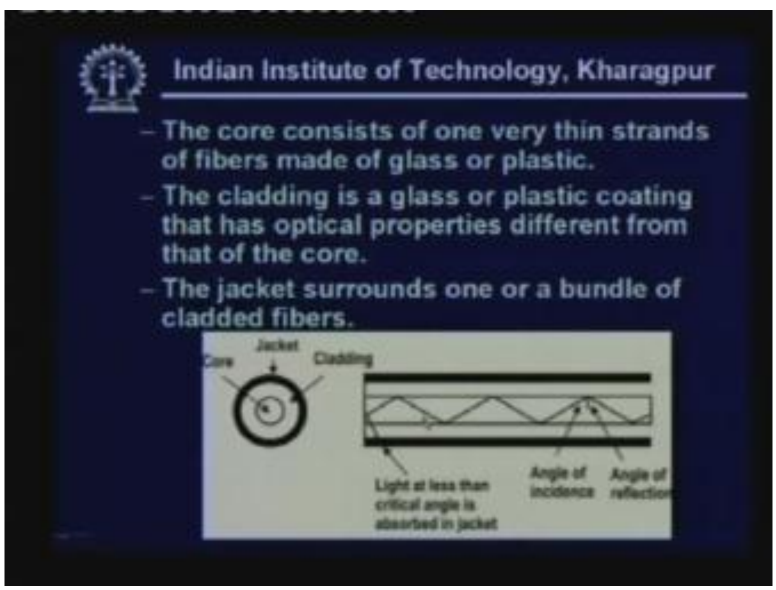

Here as you see it has got three different parts the core part and there is a cladding part and there is a jacket. The core consists of very thin stance of fibers made of glass or plastic. This particular part is made of glass or plastic (Refer Slide Time: 30:00). The cladding part is also made of glass or plastic but these two materials the core material and the cladding material they have different optical properties that we shall discuss in detail. So, although they are made of the same material plastic or silica their optical properties will be different. They will have different refractive indices as we shall see later on. Then the jackets surround one or a bundle of cladded fibers.

You can have either this kind of a single optical fiber cable or a large number of optical fiber cables and bundle them together with the help of a plastic sheet and take it from one place to another. Usually you have 4 or 6 or 8 or 16 optical fiber cables as normally it is used in pairs and for data transmission in both directions. So four eight or sixteen pairs of cables are bundled together and are taken from one place to another. The question naturally arises as how optical fiber works. The operation of optical fiber is explained with the help of this diagram.

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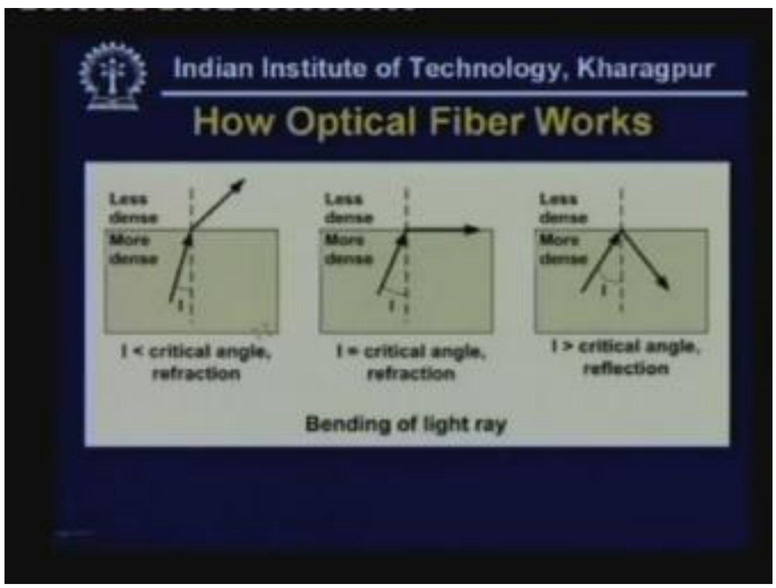

As you can see here to explain the operation of optical fiber let us consider two materials, this one is of higher density than the upper one. So the density of the lower material is more then the density of the upper material. Let's assume that this is water and this is air then this has got higher density than the upper layer.

Here the angle of incidence of this ray is less then the critical angle (Refer Slide Time: 32:30) then what is happening is this signal is going from here and it is getting refracted because of these two materials has got two different refractive indices. However, as the angle of incidence increases this i value increases gradually then this angle of refraction becomes 90 degree and whenever it becomes ninety degree ninety degree we call it critical angle of refraction.

Now if the angle of incidence is more then what happens? Then it suddenly switches from refraction to reflection. As you can see here the light is getting reflected instead of getting refracted here. So when the angle of incidence is more than the critical angle then this refraction occurs.

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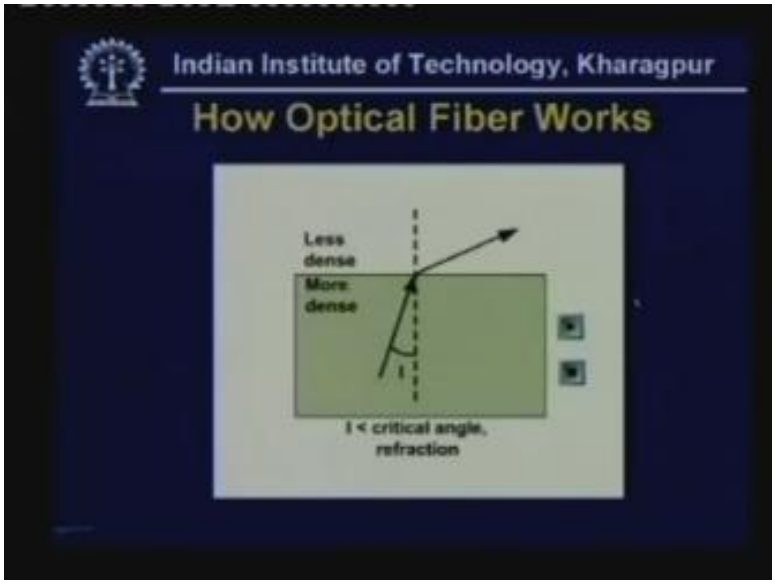

Let us see how it really happens with the help of the animation. As you can see here in this case the angle of incidence is increasing and we have reached the critical angle, this is the refracted ray and this is the incident ray.

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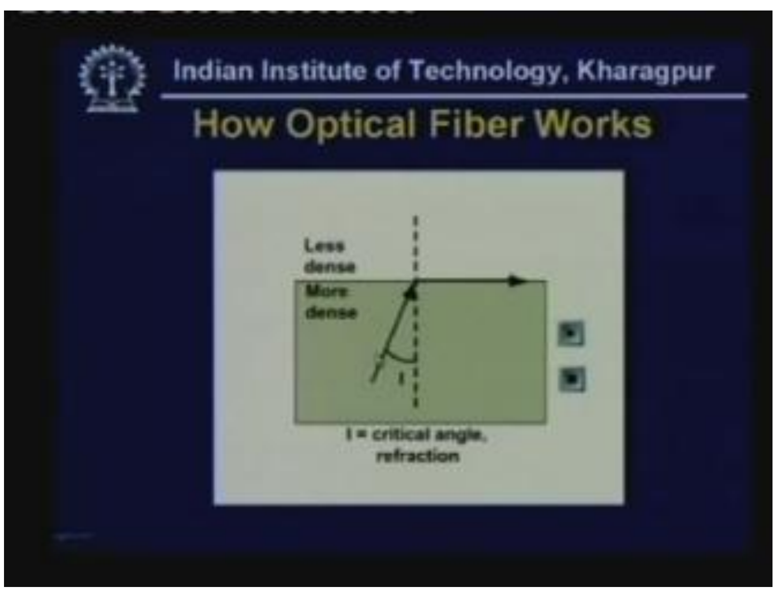

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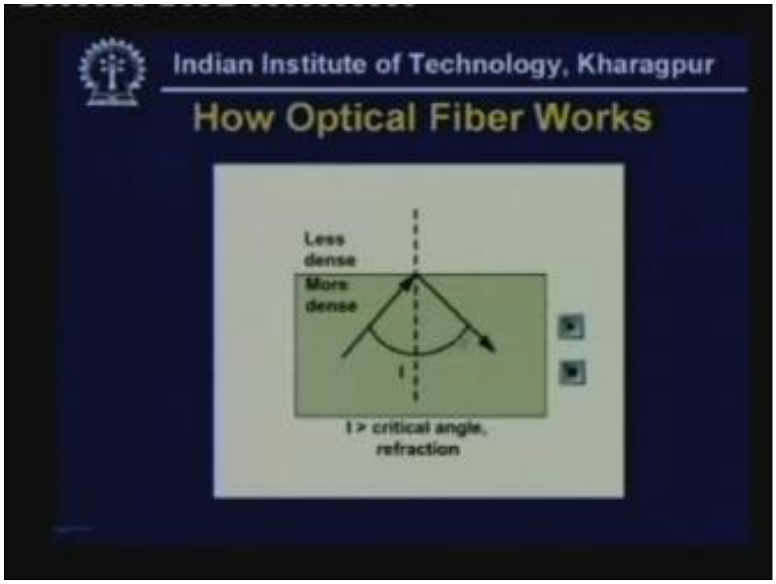

Now if we increase the angle of incidence further then as you can see now it is refracted and now this angle of incidence is same as the angle of reflection. So, angle of incidence and angle of refraction is same. So as it is increasing this angle is also increasing and as it becomes more than the critical angle then it is getting reflected rather than refracted. So here this signal is getting reflected.

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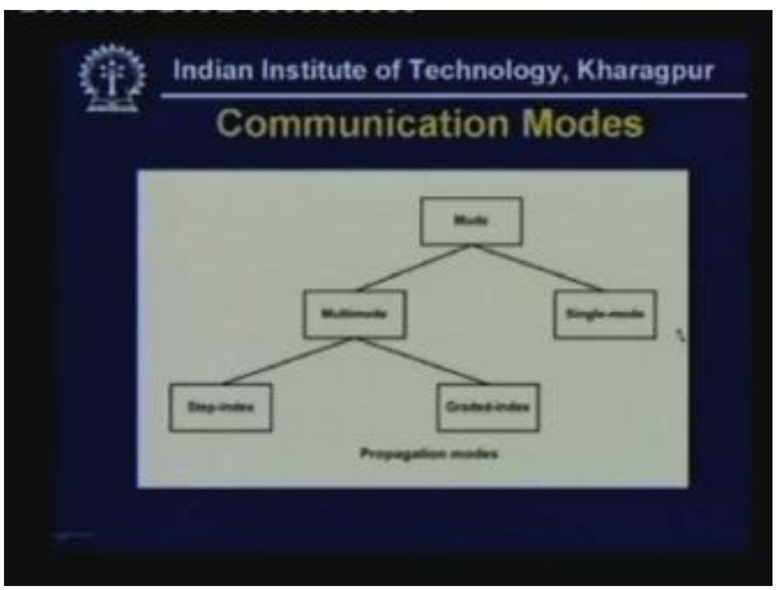

We have seen how light is reflected in optical fiber. Actually here I have shown two mediums. Actually this inner material will be the core material (Refer Slide Time: 34:50) and the outer material will be the cladding material. That will form the two materials and then the total internal reflection will take place and the light will be passing using total internal reflection as we shall see. Now based on the optical signal communication through optical fiber it can be classified into three different types. One is known as step index, actually there are two broad categories multimode and single mode. We shall see later about why it is called multimode. The multimode has got two different varieties; step index and graded index and then we have got single mode.

Let us see the three different types of optical fibers.

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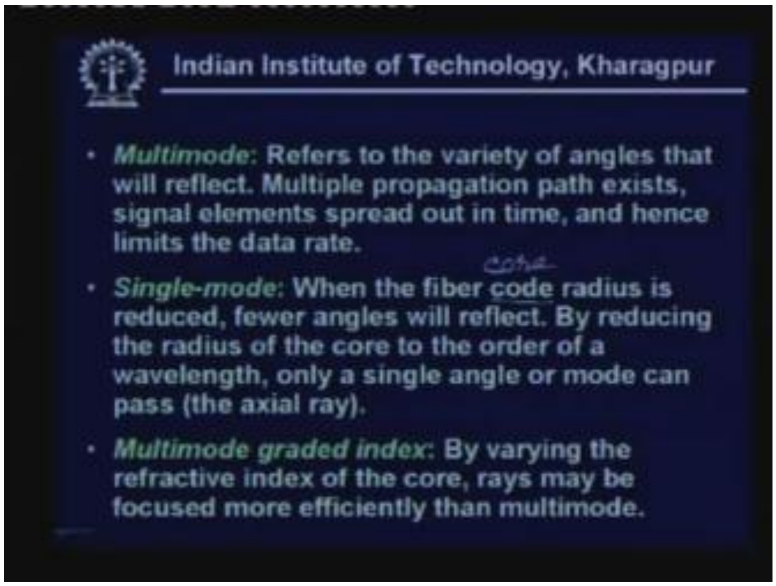

First of all this multimode refers to the variety of angles that will reflect. That means in case of multimode fiber multiple propagation path exists which means single elements spread out in time and hence limits the data rate. What is happening in this case is multiple rays will be reflected with different angles and as a result the length of the path will be different for different rays. And as a consequence they will reach the destination at different times and that will lead to distortion. That's why we are saying it will spread out in time and it will limit the data rate. So, that problem is overcome by using single mode particularly whenever the diameter of the core radius is reduced fewer angles will reflect. by reducing the radius of the core to the order of a wavelength that means say 7 nanometer, 10 nanometer etc then we may assume that only one ray is passing from source to destination. So in such a case only a single angle passes through the optical fiber called as the monomode or single mode.

Then as I mentioned there are two types in case of multimode; multimode graded index and multimode step index. Now in case of multiple step index as we shall see the core and cladding has got two distinct refractive indices. On the other hand in case of multimode graded index the refractive index of the material varies gradually from the center to the outer edge. Let us see with the help of a diagram.

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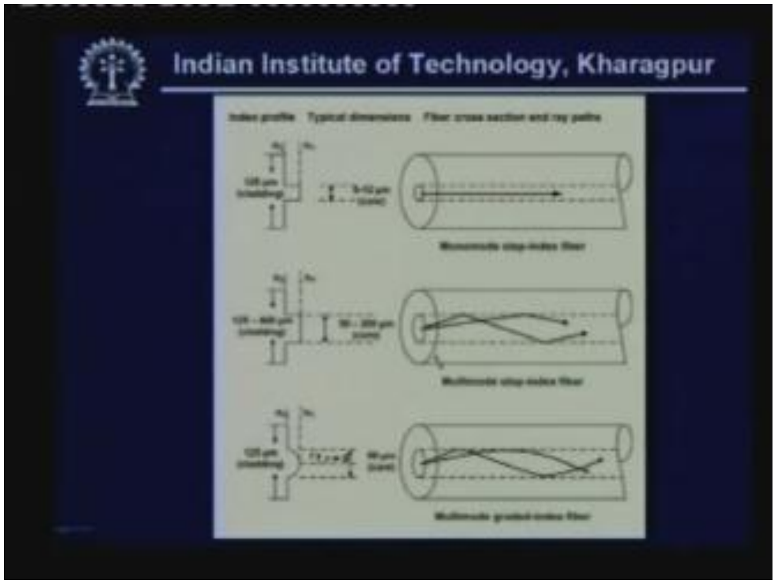

Here you have got the monomode type of step index fiber. Here as you can see diameter is very small 8 to 10 micron of the core and this is the cladding and as you can see here the refractive index of this core material is n_1 and refractive index of the cladding material is n_2 and diameter of the core is 8 to 12 micron and diameter of the cladding is 125 micron. On the other hand here you have got your multimode step index fiber. Here the diameter of the core material varies from 50 to 200 micron and diameter of the cladding can vary from 125 to 400 micron and the refractive index in this particular case for the core is n1 and the cladding is n_2.

Now, for the third variety that is your multimode graded index fiber as we can see the core refractive index is gradually changing. As you can see this is the refractive index. In the center it is 0 and it is gradually changing from n_1 to n_2, n_1 to n_2 here and here it is n_1 and here it is n_2. And as we go from here to here it is gradually changing from n_1 to n_2 and this will lead to different characteristics. Let us see how it works with the help of animation.

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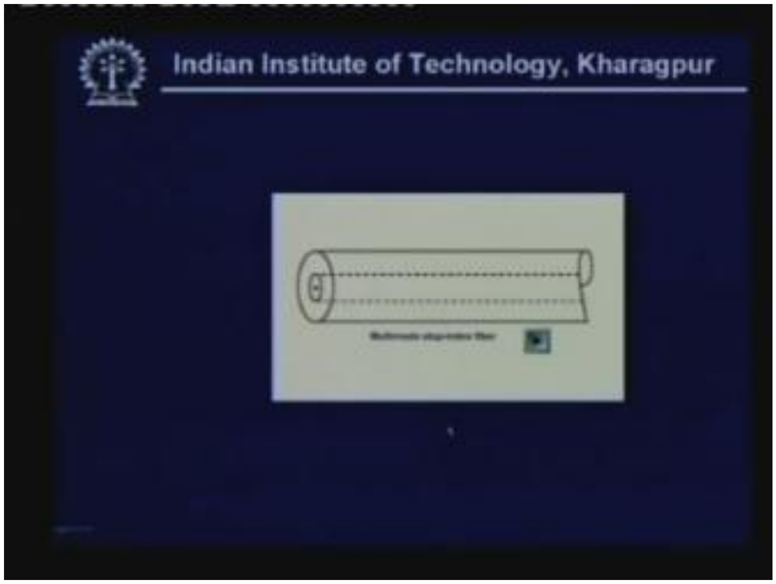

This is the case with of step index fiber. As you can see light is going through total internal reflection and it is going to the other end. now there can be another ray with a different angle of incidence and as you can see the number of reflections that it suffers is different and as a result if you measure the path length of these two rays this ray and this ray then they will be different they cannot be the same and as a consequence this leads to spread out.

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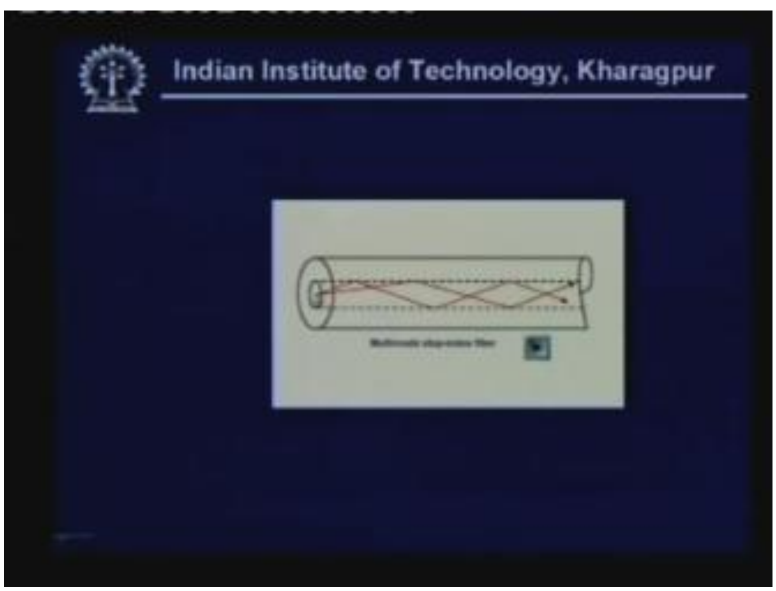

This is the case of multimode graded index fiber.

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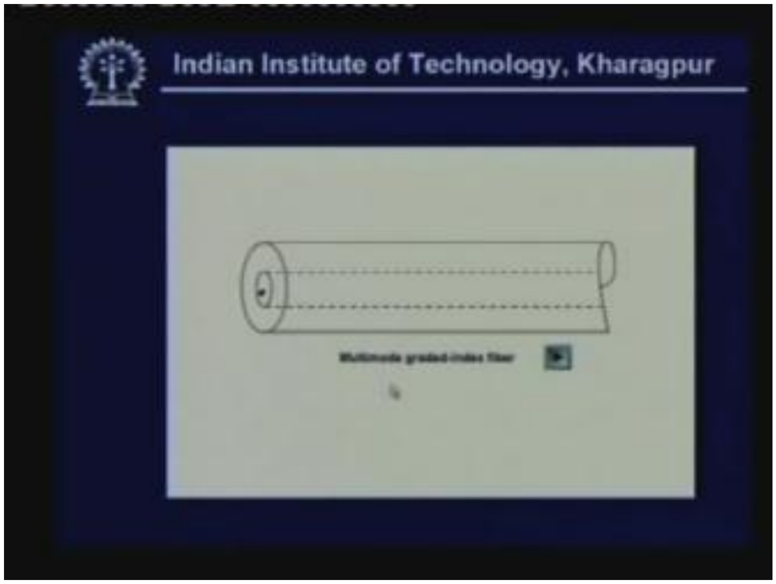

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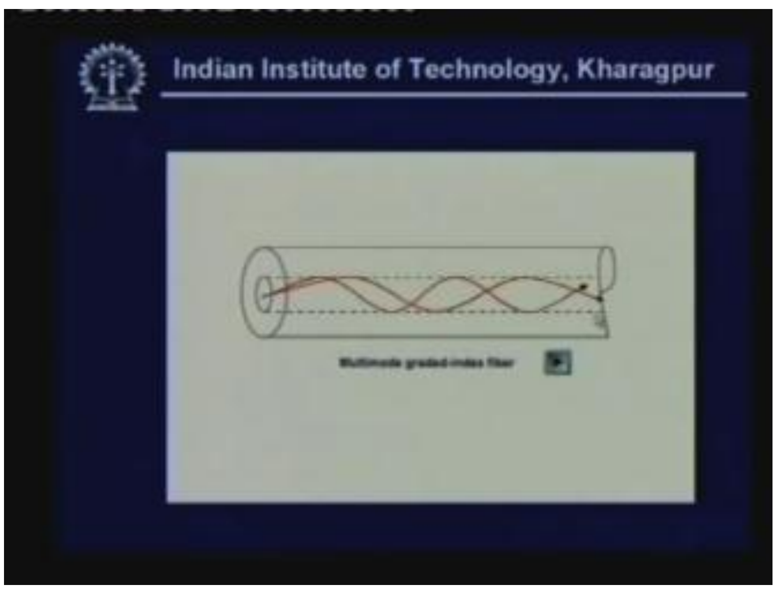

In the previous case as we have seen there is an abrupt reflection and this leads to some kind of distortion. This can be minimized in multimode graded index fiber and here the refractive index gradually changes from centre to the interface between the cladding and core the light will be gradually bending as you can see here. There is no sharp bending the light is gradually bending and going in this manner. However, bending is occurring gradually but you can have different angle of incidence and as a result multiple rays are passing from source to destination from one end to the other end.

On the other hand this is the case for monomode step index fiber.

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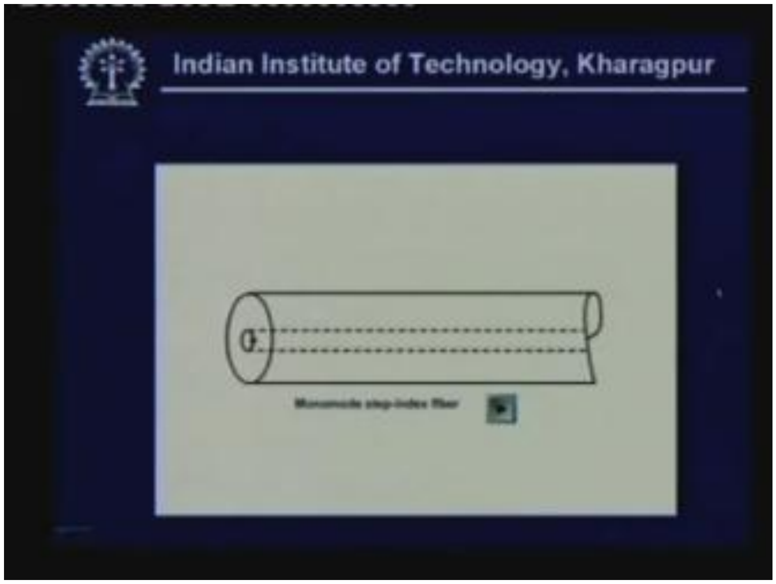

As you can see in this particular case as a single ray is going, actual ray is going from source to destination. So the question of multiple rays does not exist in case of single mode fiber. What are the consequences?

The consequence of this is the single mode fiber will have much less distortion that means the signal will not spread and normally we will call it measurement of the eye so that eye will be quite open in case of single mode fiber compared to multimode fiber. And the spacing between the repeaters will be much longer in case of single mode compared to multimode. That means in case of multimode fiber the repeater spacing will be closer than single mode fiber.

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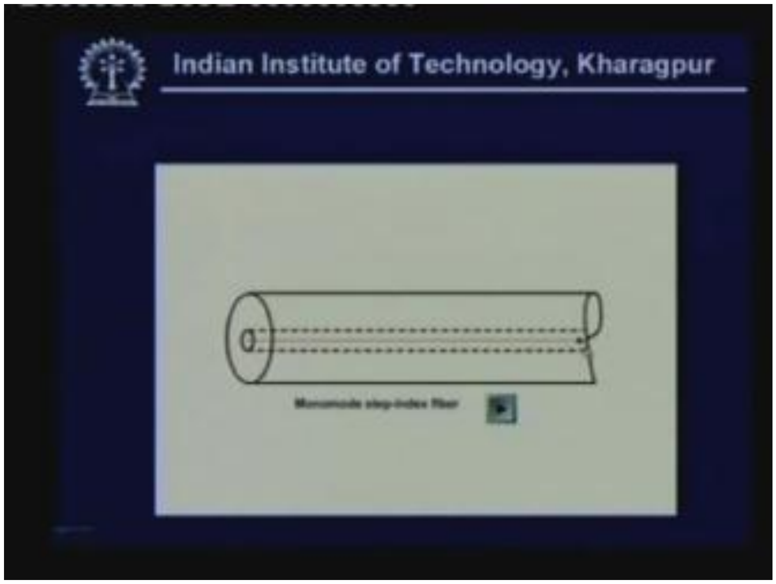

Here we have some of the different optical fiber types.

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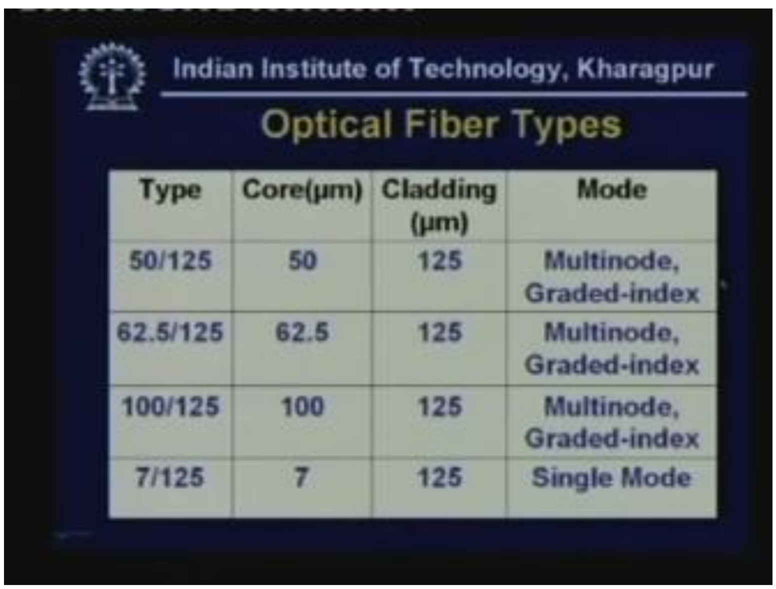

Type	Core(μm)	Cladding (μm)	Mode
50/125	50	125	Multinode, Graded-index
62.5/125	62.5	125	Multinode, Graded-index
100/125	100	125	Multinode, Graded-index
7/125	7	125	Single Mode

Here it is designated by the core diameter by cladding diameter. So here is the core diameter 50 micron, cladding diameter 125 micron, this is multimode graded index, here is another example 62.5 by 125 where 62.5 stands for core diameter and 125 micron is the cladding diameter which is also multimode graded index fiber and then we have got 100 by 125 and here the core diameter is 100 micron and cladding diameter is 125 micron so this is also multimode graded index and then 7 by 125. Here we see that the diameter is only 7 micron in case of single mode fiber or monomode fiber and cladding diameter as you can see is the same for all the four cases. Now an important parameter is the numerical aperture. Numerical aperture actually relates to the difference between the refractive indices of the core and cladding.

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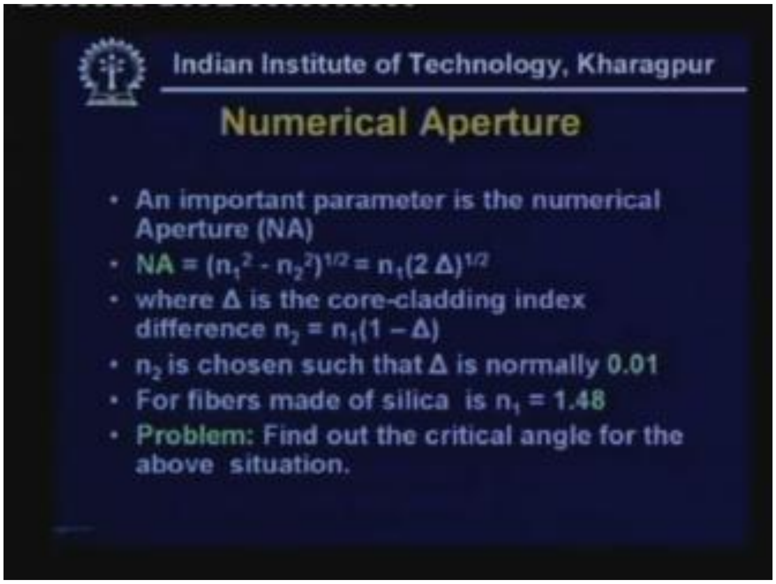

So n_1 is the refractive index of the core and n_2 is the refractive index of cladding. So this numerical aperture is square root of n_1 square minus n_2 square or you can write it as n_1 square root two delta where delta is the core cladding index difference. That means n_2 is equal to n_1 into 1 minus delta. That means core will have higher refractive index than the cladding. And the delta has a typical value of 0.011 and as you know we can use the material either plastic or silica so if we use silica then n_1 is equal to 1.48.

Now with this parameter in mind if we consider n_1 and n_2 the refractive indices of two mediums then there is a problem here which is find out the critical angle for the above situation. That means situation is where you have got two core cladding materials with difference in refractive index of delta that is 0.01. So you can find out the critical angle and this is given as a problem to you.

What are the sources of light in case of optical fiber?

Usually there are two sources one is light emitting diode. Light emitting diodes are of very low cost, it is used in almost all equipment for display purposes that can be used as a source of light, it is very cheap, it has got greater temperature range, it can withstand grater temperature range, it has longer life because it is a semiconductor material.

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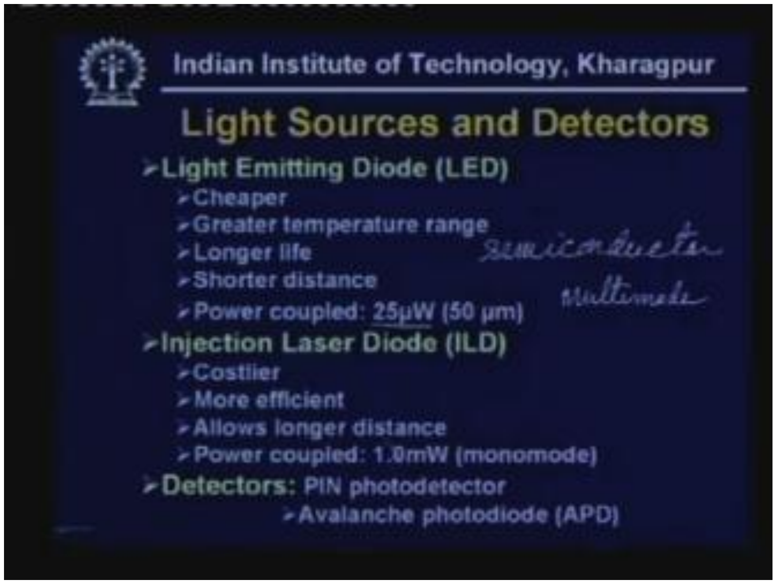

However, because the power coupled is very small for example in case of 50 micron optical core diameter the power that can be coupled is only 25 microwatt so as a result it can be used for only short distance communication and particularly it is used in multimode fiber. On the other hand there is another alternative source of light that is injection laser diode which is costlier. However, it is much more efficient than the light emitting diodes and it allows longer distance because it can coupled much higher power about 1mW in case of monomode fiber. That means in case of monomode fiber commonly that injection laser diode is used and for multimode fiber commonly light emitting diode is used.

At one end you will be using some light source ad at the other end you have to receive the signal detect the light signal. The detection of light is done with the help of two different types of photodetectors or photodiodes. One is pin photodiode or pin photodetector, another is avalanche photodiode or APD. Obviously the APD has better characteristics better signal to noise ratio than the pin photodetector. However, the avalanche photodetector is costlier than the pin photodetector.

Normally pin photodetector can be used with multimode fiber where the source of light is LED and where low cost is the primary criteria. On the other hand in case of single mode fiber the laser source is used, injection laser diode is used as a source of light and avalanche photodiode is used as the detector. Here is the attenuation characteristic of optical fiber. As you can see here the loss is dB per kilometer.

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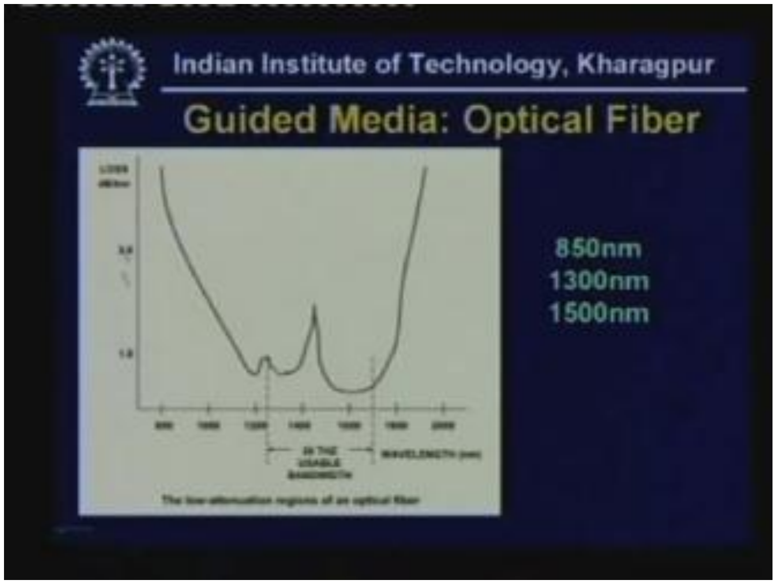

Here it goes down to one dB per kilometer so attenuation is very low and particularly it is used in three normal ranges. One is 850nm band, 1300nm and 1500nm so these three ranges are used. Here as you can see you have 1500nm, here is your 1300nm and 850nm. These are the three frequency aspect ranges which are commonly used.

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What are the advantages of optical fiber?

Optical fiber provides you higher bandwidth leading to greater capacity. As you know you can pass 2Gbps over tens of kilometers. It is used in long-haul fiber transmission and it is becoming increasingly popular in telephone network. Nowadays most of the telephone networks are used in this optical fiber communication. So you can send about 900 miles with 20000 to 60000 voice channels because of very high bandwidth of optical fiber and the material that is used is silica or plastic. It is very cheap, small in size, very light in weight as it is not a metal and it has got very low attenuation. Moreover another important property is it has got resistance to corrosive material.

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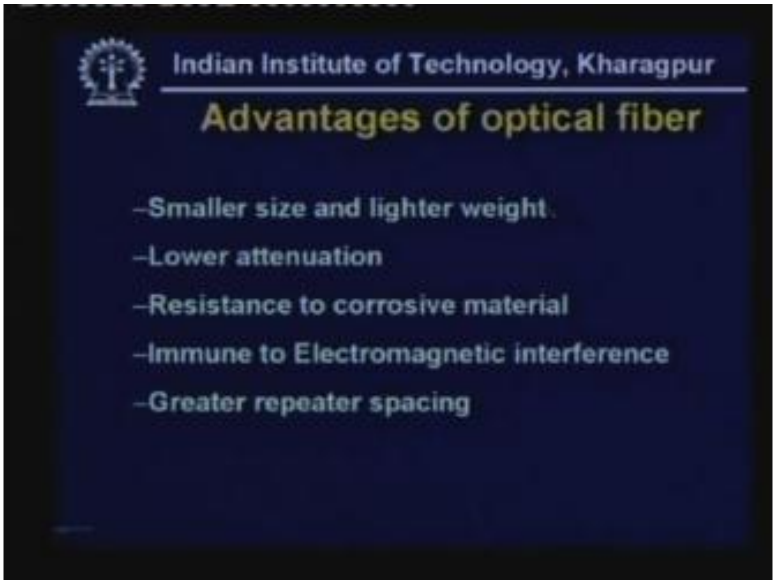

Metals get corroded, oxidation occurs. When it comes in contact with moisture and temperature that kind of corrosion does not occur in case of optical fiber material and another important property is it is immune to electromagnetic interference. So it is immune to electromagnetic interference that means it is very suitable for outdoor applications, outdoor cabling. All the outdoor cabling in Local Area Network is commonly done by using optical fiber and it has got greater repeater spacing compared to either twisted pair or coaxial cable.

The cost of the three different guided media considered can be compared in terms of cost, bandwidth, attenuation, susceptibility to external noise and security. So as you can see here the UTP Unshielded Twisted Pair has lowest cost, bandwidth is much lower, attenuation is much higher, electromagnetic interference is higher and also security-wise it is very low. We can do draping very easily each draping can be done very easily.

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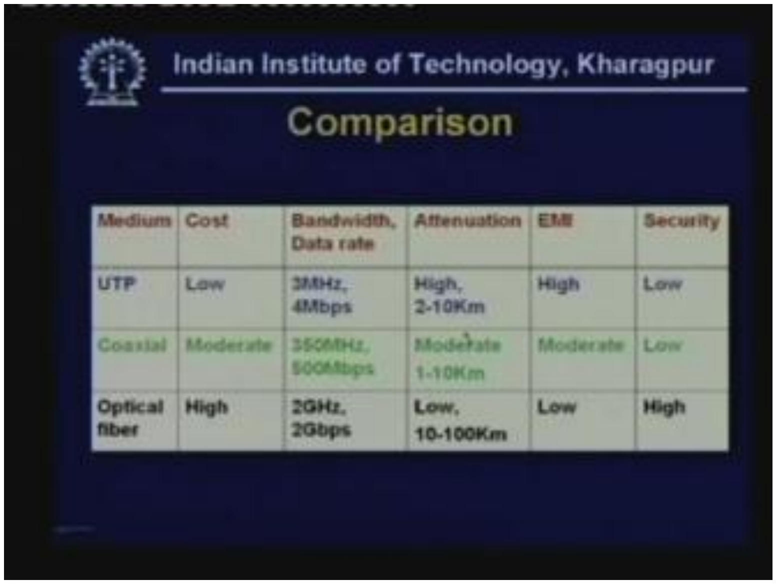

On the other hand coaxial cable which is of moderate cost with bandwidth of 350 MHz gives you data rate of 500 Mbps, it has got moderate attenuation and electromagnetic interference is moderate, security is low more or less same as your UTP. On the other hand optical fiber has got little higher cost, very high bandwidth 2GHz, you can have data rate of 2 gigabits per second, attenuation is low, you can have repeater spacing of 10 to 100 kilometers and EMI interference is low because electromagnetic interference cannot take place with light and it has got higher security, it is very difficult to get data from optical fiber.

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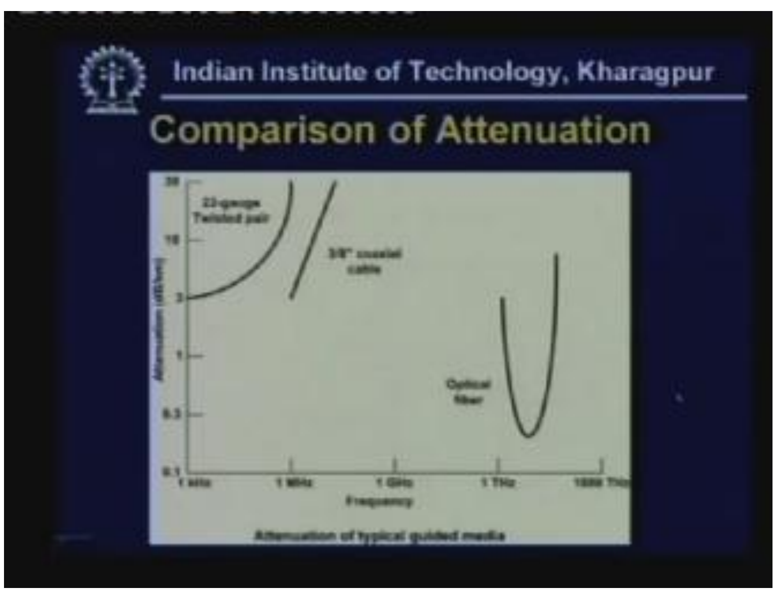

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So here if you compare the attenuation characteristics as you can see attenuation is much low for optical fiber compared to twisted pair and coaxial cable. the main difference between twisted pair and coaxial cable is that coaxial cable has got higher bandwidth compared to twisted pair.

Here are the review questions:

1) What parameters the quality of transmission depends in case of guided transmission media?

2) Why wires are twisted in case of twisted pair of transmission medium

3) Give a popular example where coaxial cables are used for band broadband signaling.

4) Find out the critical angle for a step indexed optical fiber for n_1 is equal to 1.04 and delta is equal to 0.04.

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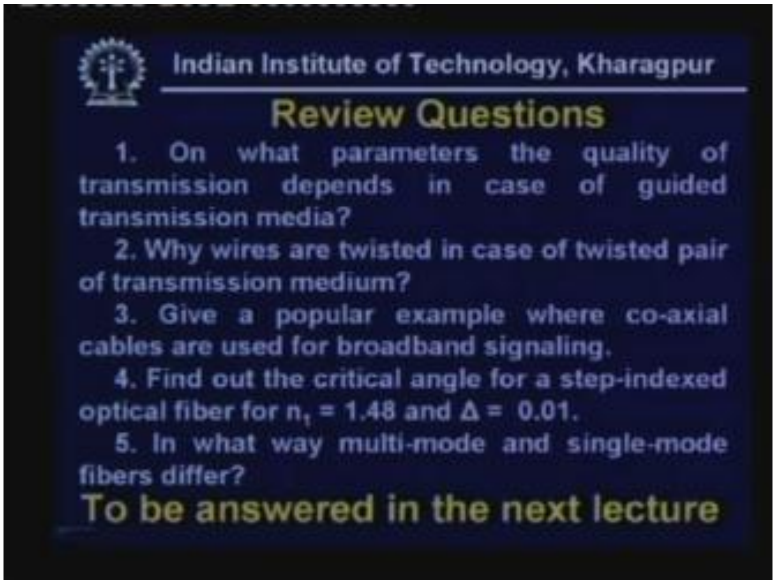

5) In what way multimode and single mode fibers differ?

So these are the five questions to be answered in the next lecture.

Here are the questions that I gave in the previous lecture.

Let us look at the first question, answer is attenuation. Attenuation will be equal to 10 log10 1 by 50 is equal to minus 16.9 dB.

2) Assuming there is no noise in a medium of bandwidth 4 KHz, determine channel capacity for encoding level four.

As you know the equation the C is equal to Blog2m, here it is log2 (4) this gives us 16 Kbps. So this is the channel capacity that is possible in this case.

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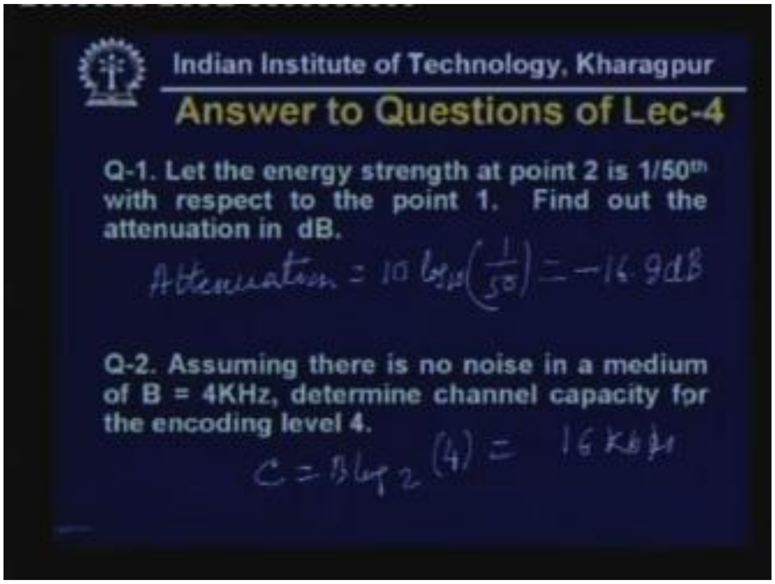

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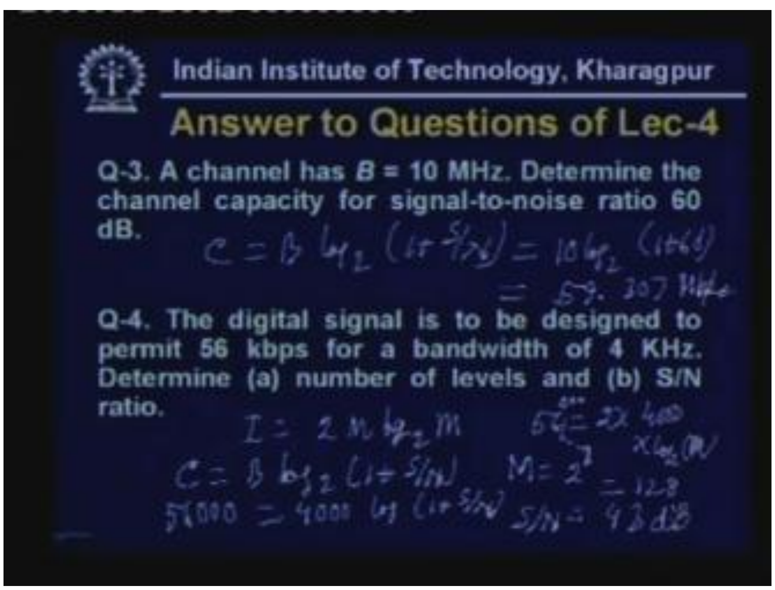

3) A channel has a bandwidth of 10 MHz determine the channel capacity for signal to noise ratio 60 dB. So as we know the formula C is equal to Blog2 (1 plus S by N).

So with the help of this we can find out so 10 $\log_2$ 1 plus 60 gives you 59.307 and here it is MHz so Mbps so this is the maximum possible channel limit you can say 59 Mbps

4) The digital signal is to be designed to permit 56 Kbps for a bandwidth of 4 KHz determine the number of levels and signal to noise ratio. This can be calculated by using two different formulas. In the first case you have to use this formula i is equal to 2 into M $\log_2 M$. Here you have to find out the M and i is given already as 56 so 56 is equal to 2 into 4000 into log2M. From this you will get M is equal to 2 to the power 7 that will be 56 kilobits so you have to have 0s that is 56000 zeros 7 is equal to 128 levels.

Similarly you can find out the signal to noise ratio from this equation. That means signal to noise ratio will be found out from this formula C is equal to $B\log_2$ (1 plus S by N) so here C is given, B is given so a signal to noise ratio has to be found out. C is equal to 56000 is equal to bandwidth is 4000 $\log_2$ 1 plus signal to noise ratio has to be found out. From this we can find out S by N is equal to 43 dB. So here we have the answer for all the questions that were asked in the last lecture, thank you.