Data Communication

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Lecture No # 7

Transmission of Digital Signal-I

Hello and welcome to today's lecture. In the last couple of lectures we have discussed about various transmission media.

Now we shall focus on a signal that we shall transmit through the communication media. And today we shall discus about transmission of digital signal and it is the first lecture on the transmission of digital signal.

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So, topic is transmission of digital signal minus I. here is the outline of the lecture. First I shall give a brief introduction then we shall discuss the important characteristics of line coding then popular line coding techniques such as unipolar, polar and bipolar then we shall consider a very important characteristic that is the modulation rate of various codes that we shall discuss in this lecture then we shall compare the line coding techniques that we shall cover in this lecture.

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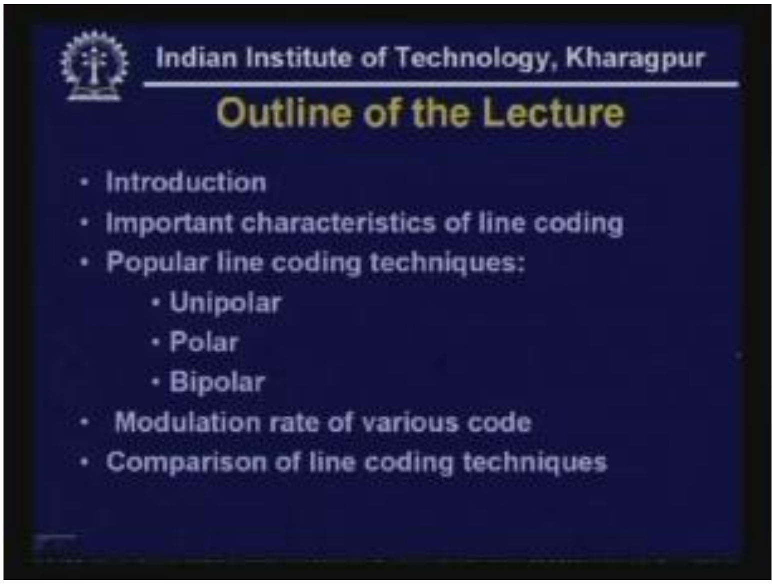

And obviously on completion the students will be able to explain the need for digital transmission, why digital transmission is required. They will be able to explain the basic concepts of line coding, explain the important characteristics of line coding, they will be able to distinguish among various line coding techniques such as unipolar, polar and bipolar and they will be able to distinguish between the data rate and modulation rate.

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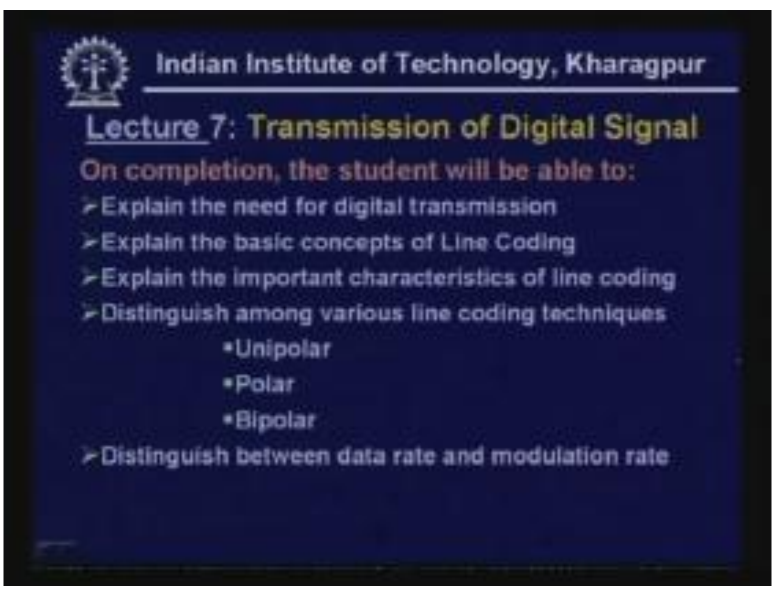

Before I discuss about the transmission of digital signal let us very quickly give an overview of the transmission media that we discussed in the last two lectures.

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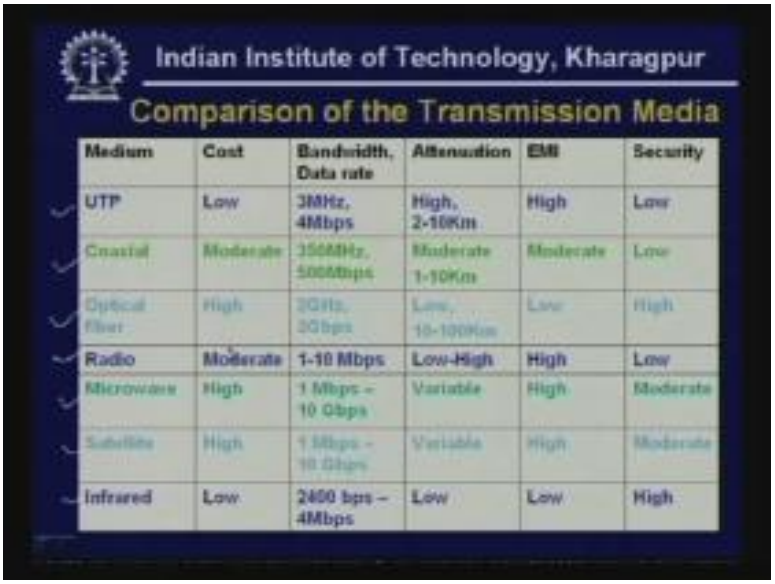

Medium	Cost	Bandwidth, Data rate	Attenuation	EMI	Security
UTP	Low	3MHz, 4Mbps	High, 2-10Km	High	Low
Coaxial	Moderate	350MHz, 500Mbps	Moderate 1-10Km	Moderate	Low
Optical Fiber	High	2GHz, 2Gbps	Low, 10-100Km	Low	High
Radio	Moderate	1-10 Mbps	Low-High	High	Low
Microwave	High	1 Mbps – 10 Gbps	Variable	High	Moderate
Satellite	High	1 Mbps – 10 Gbps	Variable	High	Moderate
Infrared	Low	2400 bps – 4Mbps	Low	Low	High

As you remember we discussed about two types of transmission media; the guided media and unguided media. The first few here for example UTP, coaxial cable, optical fiber these three belong to the guided transmission media. On the other hand radio, microwave, satellite and infrared belong to unguided transmission media. And here the first column gives you the cost comparison. obviously the UTP is of lowest cost, coaxial has moderate cost, optical fiber has got high cost, radio communication has got moderate cost, microwave has got high cost, satellite has got high cost and infrared has got low cost.

In terms of bandwidth as you know UTP has got lowest bandwidth and optical fiber has got the highest bandwidth then so far as the unguided media is concerned microwave gives you the highest bandwidth and of course microwave is used in two cases. The first one essentially terrestrial microwave and second one is satellite microwave which gives you high bandwidth.

In terms of attenuation we find optical fiber attenuation is the lowest and of course for microwave as you can see the attenuation is variable. Depending on the atmospheric condition it will vary.

Electromagnetic interference is high in the first two cases UTP and coaxial cable. in case of optical fiber it is minimum as you can see here, then for radio that electromagnetic interference is very high, for microwave and satellite these are also high. for infrared it is low.

And so far as security is concerned the UTP and coaxial cable is not at all secured they are prone to …….. dropping and on the other hand optical fiber has got very high security (()) is very very difficult and on the other hand radio wave since it is broadcasting nature it has got very low security, microwave and satellite has got moderate security because it is not that easy to receive the signal from terrestrial microwave or satellite where you have to set up an antenna which will require good amount of effort. On the other hand infrared has got high security because it is within a room.

So with this background now we shall discuss the transmission of digital signal.
But before doing that let us consider the various options available to you. As you know you can have digital data and you can get it converted into digital signal by suitable encoding technique similarly you can have analogue data which can also be converted into digital signal by suitable encoding then you can have analog data which can be converted into analog signal by suitable modulation technique. We shall discuss this later in this lecture then we can have digital data which can be converted into analog signal by suitable modulation techniques. So these are the various options available to us.

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The question arises as what type of signal we should use? Is it digital signal or analog signal? As we shall see each of these signals has its own characteristics and features, good points and bad points and as we know a digital signal requires a low pass channel or transmission media and bandwidth requirement is more. on the other hand analog signal requires a bandpass communication media or bandpass channel. And most of the practical channels that we shall encounter are bandpass in nature as we shall see.

So depending on the situation and the bandwidth availability we shall choose either digital signal or analog signal. So in some situation we shall use digital signal and in some other situation we shall go for analog signal so we shall use both.

So in this lecture we shall start with the digital data and digital signal. And as you know the bandwidth of the medium will play a very crucial role when we send through transmission media. We have to match the bandwidth of the signal with the bandwidth of the transmission media so that the signal can pass efficiently without much attenuation, without much distortion and this will require a good encoding technique which we shall discuss in this lecture. So in this lecture we shall consider digital data which is converted into digital signal and the technique that is being used is known as line coding. Line coding technique is used for converting digital data into digital signal. This can be explained with the help of the simple diagram.

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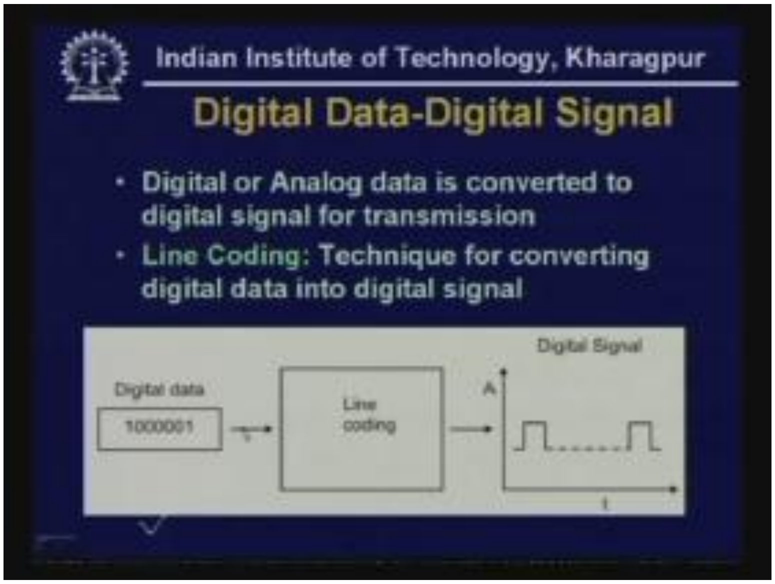

here you have got the digital data 1000001 this data may be coming from some memory of the computer or may be stored in the digital disk and that we shall apply to a system or we shall do line coding which will convert it into a signal as you can see here, here you have got the signal. This signal can be transmitted through the communication media.

Line coding is the technique that we shall discuss today.

What are the important characteristics that we have to consider for line coding?

Here are some of the important characteristics are given. First one is the number of signal levels. As we do the encoding then the number of signal levels can remain 2 because it is binary signal binary data it can be coded with two levels or you can do multilevel encoding. for example as it is shown here your data has got two levels 0 and 1 and the signal has also got two levels so two signal levels one is 0V and the other is 2A volt that means 2A is the amplitude and 0 is the amplitude. So it has got two different levels.

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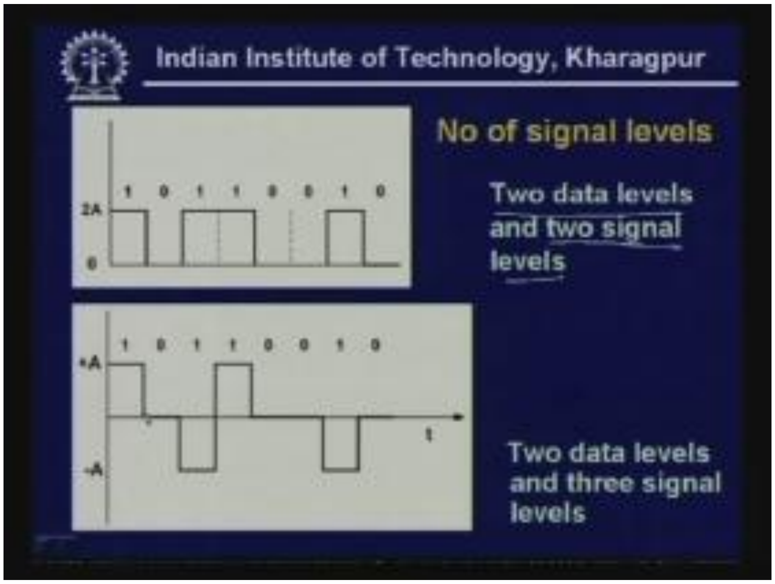

Here you have two data levels and two signal levels. This is an example.

And at the bottom as you can see you have two data levels 1 0 1 0 so it is binary data but it has got three signal levels plus, 0 and minus A that is plus A, 0, minus A that means positive voltage, negative voltage and 0 voltage. So as you can see here you have got positive A then 0 here then negative A here. These are the three levels that is being used here for the purpose of encoding. And whenever you do multilevel encoding the information that is contained can get changed and as we know I is equal to 2B into $\log_2 M$ that means the number of signal levels that is being used will decide the information rate where B is the bandwidth of the medium so if you get 2 Achieved higher data information rate we can go for multilevel encoding if necessary.

Then comes the question of bit rate versus baud rate.

As I have explained in the last lecture the bit rate is essentially the data rate the rate at which the signal is transmitted. On the other hand the baud rate is essentially the number of signaling elements. So the number of signaling elements used can be more than the data rate or can be less than the data rate. So, if you use multi-level encoding then the baud rate will be less than the data rate. in some cases the baud rate can be more than the data rate. Hence we have to decide on that but obviously we shall prefer lower baud rate to achieve higher data rate of transmission through the transmission medium.

Then comes the question of DC component. As we know whenever we try to send signal through a transmission media it is difficult to send DC signal because of the presence of transformers, capacitor in the equipment through which we are sending the signal. So, because of the presence of transformer and capacitor DC component the DC component will be blocked which will lead to attenuation.

But sometimes there will be DC component. for example if it is encoded in this manner and if you have got 0V and say another volt is plus k then as you can see this will be for 1, this is for 0 and this is even for 1 and so on so the average value will have a DC. So that DC component will not pass through the medium. That's why we shall try we shall try to do the encoding in such a way that DC component is not present. That means we shall transform the sig data into a form of signal which will not have DC component.

Then comes the question of signal spectrum.

Signal spectrum will play an important role because the bandwidth of the signal that we are trying to send through a medium will decide whether it will be distorted or not. That means the bandwidth has to match with the transmission media so signal spectrum has to be taken into consideration when you do the encoding.

Noise immunity: We have to see whether the encoding that we do has higher noise immunity or not. As we have seen some of the transmission media has got inherent noises. We have already discussed in the transmission impairment lecture. There we have seen that in presence of noise we have to transmit signal and obviously if the encoding is done such that it has higher noise immunity it will be beneficial. Then we can try to do encoding which will help us in detecting errors. Whenever the signal is sent through the communication media because of various types of noises error is introduced in the signal. Thus at the receiving end if you can detect error because of the encoding use that will be helpful. So we shall look into it

Then comes the question of synchronization.

In synchronization we shall be sending signal. This is sent by the transmitter. We want the same thing to be received at the receiving end. But if this position is not matched then the receiver's end must be able to identify when this is going from low to high or when it is going from high to low.

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That means these positions have to be identified at the other end. Usually a clock is used at the transmitting end to generate the signal. Similarly at the receiving end a clock is used to regenerate the signal. Now these two clocks may not have exactly the same frequency so that may lead to lot of synchronization. Not only they may not have the same frequency but their phases may also be different so it is necessary to synchronize them. And for the purpose of synchronization there are 2 alternatives. What can be done is a separate line can be used, a separate channel can be used for sending the clock to the receiver. The receiver can use that clock for receiving the data but that is not really feasible because of high cost. So commonly it is necessary to regenerate clock from the received data with the help of some special hardware such as phase lock loop.

However, this regeneration of clock at the receiving end is possible only if when the signal has got sufficient number of transitions. That means suppose you are sending a long sequence of 0 or a long sequence of 1 if the encoded signal does not have enough number of transitions then the phase lock loop will not be able to regenerate the clock so it is necessary to have enough number of transitions in the signal for the purpose of synchronization. Therefore while doing encoding we have to take into consideration this synchronization aspect. Finally the cost of implementation we have to see because ultimately you have to encode the signal with minimum cost. So these are the important characteristics you have to look into for encoding.

Now let us see what are the various line coding schemes that is commonly used. The line coding techniques can be broadly divided into three types; unipolar, polar and bipolar. So these are the three basic schemes that is being used.

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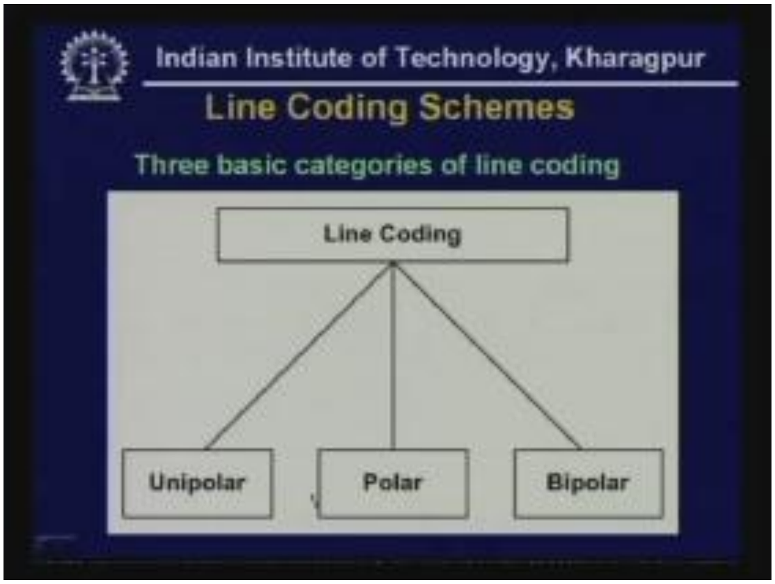

The unipolar is the simplest and here you have got the two voltage level. Uni means 1 so you are sending only voltage of one polarity say 2A.

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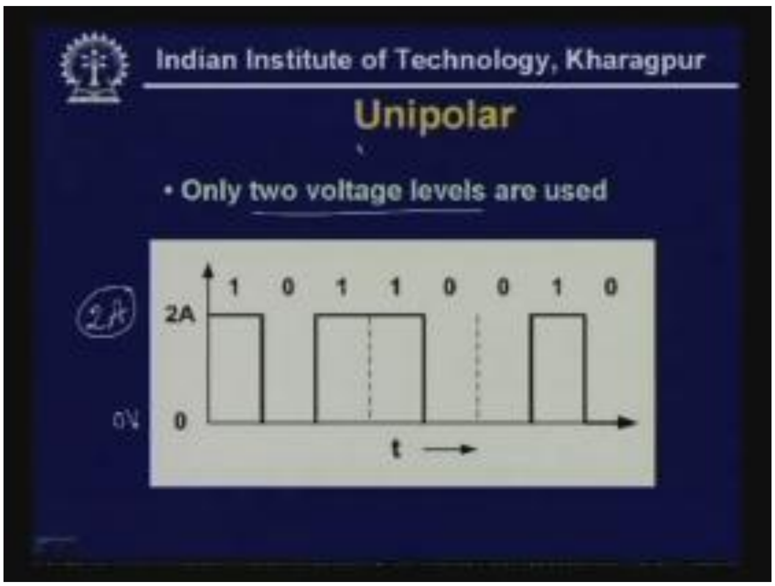

And here you are not sending anything that is considered to be 0V. That means when you are not sending anything that is 0V when you are sending something that is 2A volt. So only one polarity signal you are sending and when you are not sending that is been considered as 0V. That's why although you are sending one polarity we may consider it as two voltage levels. So don't get confused whenever we say unipolar at the same time two voltage level. Essentially we are sending voltage of one polarity but whenever the volt signal is not present then we consider it 0.

For example, for 1 we are sending voltage of 2A and when it is 0 we don't send anything. Similarly for 2A again we send 2A voltage and for 0 don't send anything. That means the data is represented by voltage level. That means one is voltage level 2A and 0 is no voltage or no signal is being sent. That's how this unipolar encoding is done.

Unipolar encoding has got the following characteristic. It uses only one polarity of voltage level as I mentioned and here the bit rate is same as the data rate. The means the modulation rate or baud rate is same as the data rate. In other words you have got only one signaling element per bit. Unfortunately as you have seen we are using signal of only one polarity and as a consequence there will be DC component of the average value of the signal that will be received at the other end will have DC so there will be DC component present in signal.

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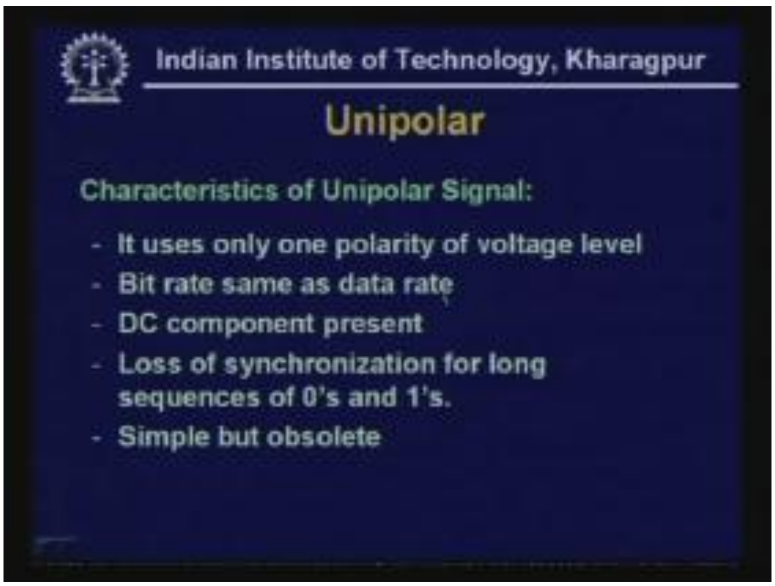

And as you can see from this signal whenever you have got long sequences of 0s or long sequences of 1s only one signal level is transmitted or no signal is transmitted. In other words there will be no transitions and that will lead to loss of synchronization for long sequences of 0s and 1s. So this unipolar scheme is possibly the simplest but it is obsolete. It is not used because of the limitation.

For example, the DC component is present which is a bad feature, loss of synchronization is a bad feature and of course data bit rate and data rate is same. We may come we may not consider it go good but it is not definitely bad. But it is simple because it uses only one polarity of signal. Let us see what are the polar schemes used.

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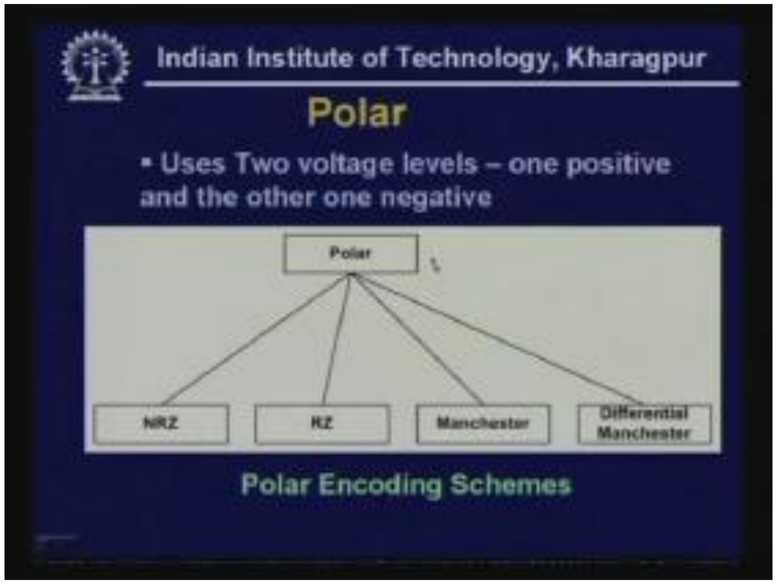

In case of polar essentially two voltage levels are used; one is positive and the other one is negative. So we are using one positive voltage and one negative voltage and the polar encoding scheme has got several alternatives like NRZ Non-Return-to-Zero, RZ Return-to-Zero, Manchester encoding, Differential Manchester encoding. so these are the four different encoding schemes available under polar encoding.

Let us consider their features one after the other, Non-Return-to-Zero that is NRZ. In this particular case as you can see from this diagram voltage level is constant during a bit interval. That means for 1 it has got two varieties NRZ L and NRZ I.

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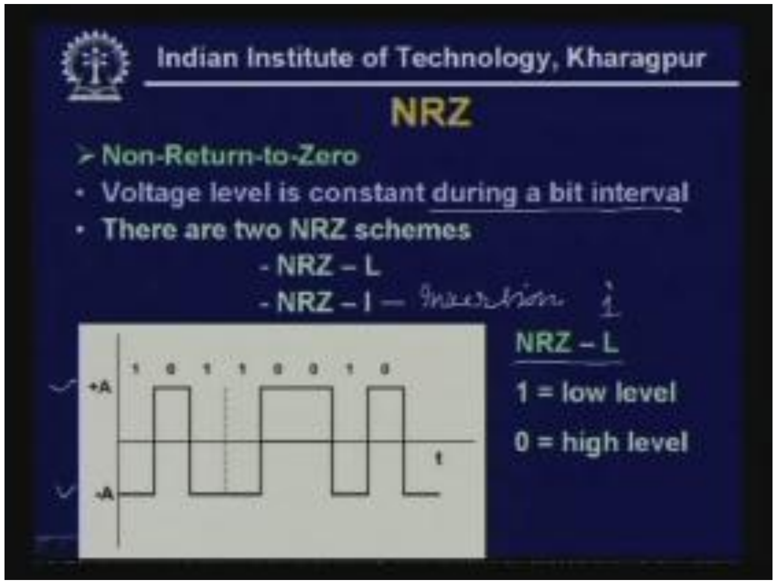

First let us consider the NRZ L. in case of NRZ L Non-Return-to-Zero L stands for low level. Here it means that the binary value 1 is represented by low level. As you can see here binary value one is represented by low level minus A and 0 is represented by high level plus A. So here we are using signals of two polarity plus A and minus A and these two polarities are use to represent a binary 0 and 1. So 1 is represented by A the minus A polarity voltage and 0 is represented by plus A. That means the signal levels state of the data is represented by signal level and that remains constant during a bit interval as I mentioned. So you see here that during the inter bit interval the data is either plus A or minus A (Refer Slide Time: 22:40). So when it is 1 it is minus A and when it is 0 it is plus A.

Let us look at the other alternative NRZ I where I stands for inversion. Here in case NRZ I what we are doing is for each one in the bit sequence the signal level is inverted.

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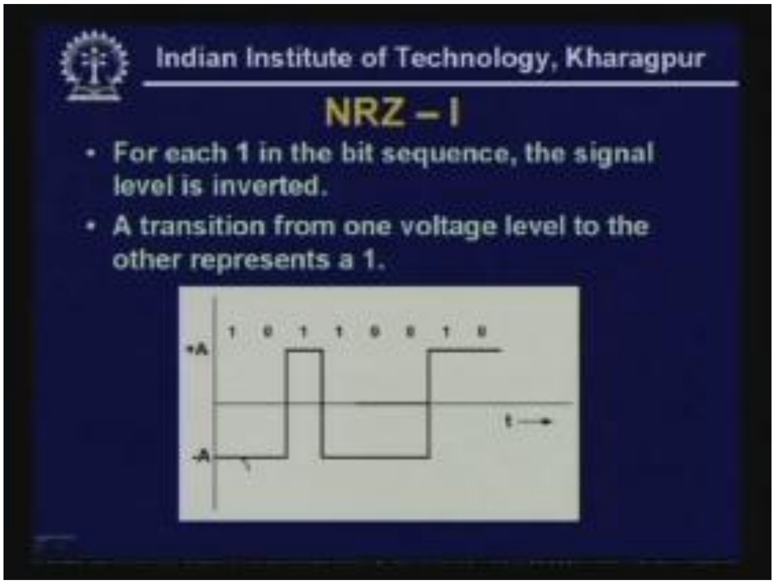

Here as you can see this is your 1 for which it was minus A. whenever the next A is encountered you can see here it is making a transition from minus A to plus A. Another one is here so in this boundary again it is making transition from plus A to minus A. Here there are two 0s so there is no transition. So whenever a 1 is encountered the signal is making a transition or it is getting inverted from the previous signal level.

So here it was inverted from minus A to plus A and here it was inverted from plus A to minus A because of the presence of this one, again another one is encountered here, here it is inverted from minus A to plus A. This is how a transition from one voltage level to the other voltage level takes place in this particular case. In the previous case as you can see (refer Slide Time: 24:11) whenever there is a transition from 1 to 0 the data changes from 1 to 0 so there is a transition or in the next case whenever consecutive 1s are there or a 1 is encountered there is transition.

But whenever you have a long sequence of 0 then there is no transition in the signal and that will lead to loss of synchronization. So here are the characteristics of this NRZ encoding. Here you can see it has got two voltage levels plus A and minus A, here the bit rate is same as the data rate because the number of signaling elements per bit is 1 so data rate is same as the baud rate. So in other words it is M is equal to 2.

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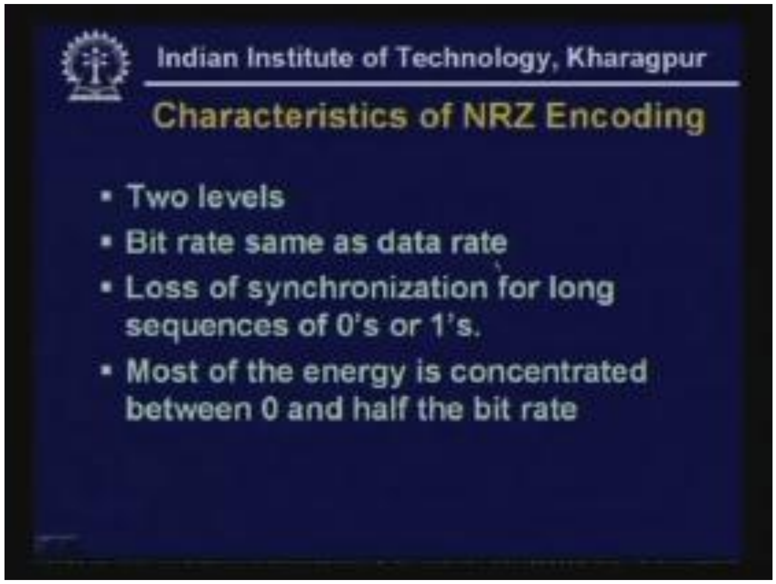

Loss of synchronization for long sequences of 1s and 0s, whenever you send long sequence of one or long sequence of 0 you will find there will be loss of synchronization. And in this case if you look at the signal spectrum you will find that most of the energy is concentrated between 0 and half the bit rate as it is shown in this diagram.

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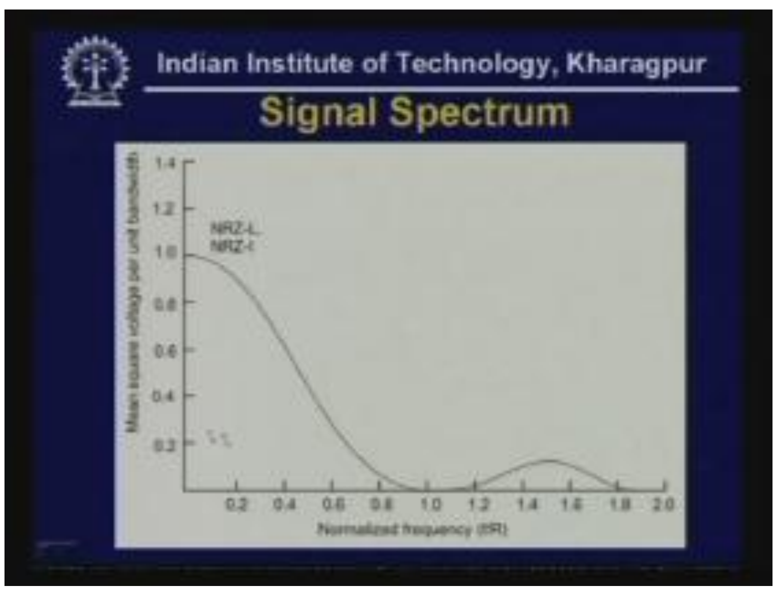

Here you find for NRZ I and NRZ L the signal spectrum is shown here. On the x axis you have got normalized frequency f by r where r is the bit rate and means square voltage per unit bandwidth. So here you find most of the energy is around this region that is half of the bandwidth. That means this is one, this is the bandwidth of the signal. You can see here that most of the energy is between DC and the middle point of the signal around 0.5. So here major part of the signal is shown and most of the energy is concentrated between

0 and half the bit rate. So this is the characteristic of NRZ encoding both NRZ L and NRZ I.

Synchronization has been found to be a major concern in the two schemes that we have discussed. To overcome that we can use RZ encoding that is known as Return-to-Zero. So here what we do is for each bit it returns to 0. If it is 1 it is 1, if data is 1 it is plus A then in the middle point of the bit it returns to 0 and it remains there and for 0 the signal value is minus A again in the middle point it returns to 0.

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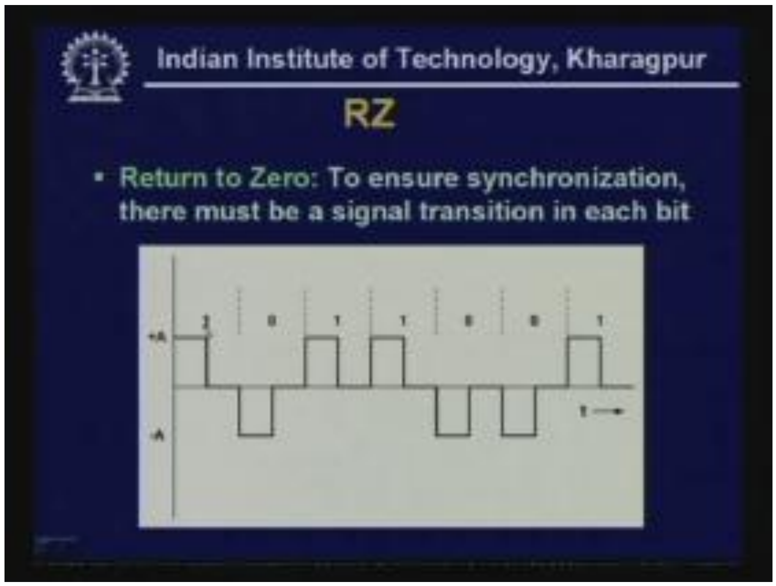

So here we see for each bit there are two transitions. One is from low to high and another is high to low. Thus two transitions per bit is taking place irrespective of whether is 0 or 1.

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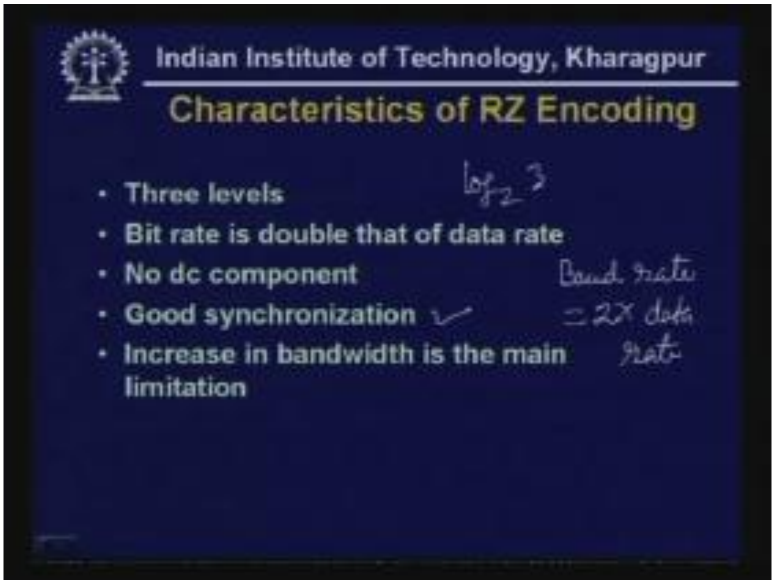

So if you have long sequences of 0 or long sequences of 1 you will not face any difficulty because the number of transitions is quite large and as a result it is very good for synchronization. However, it uses three levels of encoding so it is possible to have $\log_2 3$ that means the information content can be more but unfortunately you are encoding only a two data that means the data rate is not increased although it has the capability to have higher information rate.

So however the bit rate is double than that of data rate because the number of transitions it is making is not at all an efficient encoding so here baud rate will be equal to two that of data rate so this is definitely bad that the signal requires higher bandwidth than the data rate. However, it provides you good synchronization as you have seen. And the increase in bandwidth is the main limitation or concern because of this the signal has got double the bandwidth than the data rate. Data rate is multiplied by two to the baud rate and as a consequence RZ encoding is good from the view point of synchronization but it is bad from the view point of the bandwidth requirement.

Let's see how we can go for a better scheme. This Manchester encoding is also a bipolar encoding. Here we are also using plus A and minus A the signals of two polarity levels. However, as you can see we can consider it that each signal element is divided into two phases biphase, two phases the first part and second part. So in Manchester encoding there is a mid-bit transition so mid-bit transition is taking place.

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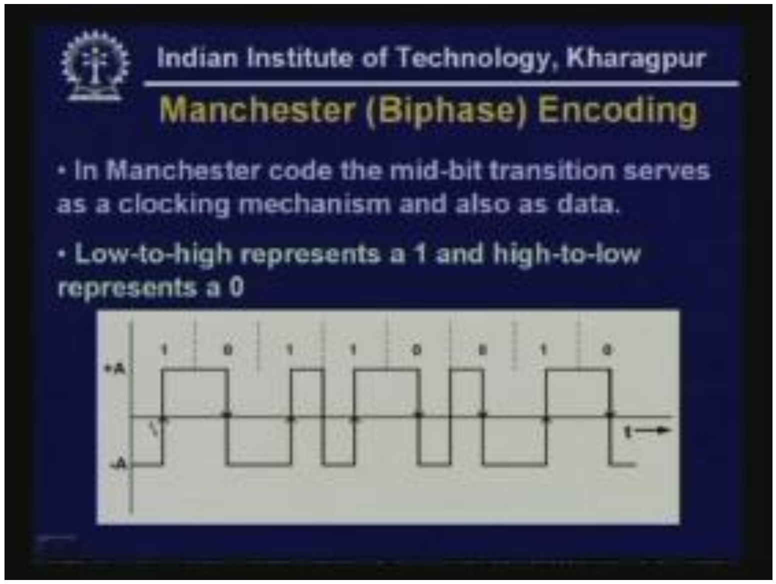

So each mid-bit transition for example for one the transition is from minus A to plus A for 0 it is from plus A to minus A. So, if the next bit is one then it has to go from minus A to plus A so there is no need of transition in the middle, however, the next bit is 1 and here it will make transition from low to high (Refer Slide Time: 30:26) and in this middle position it has to again make transition from low to high so in the beginning it is making transition from high to low. Hence it is possible to have low to high transition. That means whenever you have two consecutive 1s as we can see the number of transitions will be low to high, high to low then low to high.

On the other hand whenever you have got two consecutive 0s again there will be transition from high to low, low to high and again from high to low. So the number of transitions is more for consecutive 1s and consecutives 0s. However, when you have got consecutives of 0s and 1s then as you can see the number of transitions is one per bit.

However, you have got enough number of transitions. this is Manchester encoding where the signal levels are represented by the number of transitions, that is it is essentially it is making from high to low or low to high in the middle bit position.

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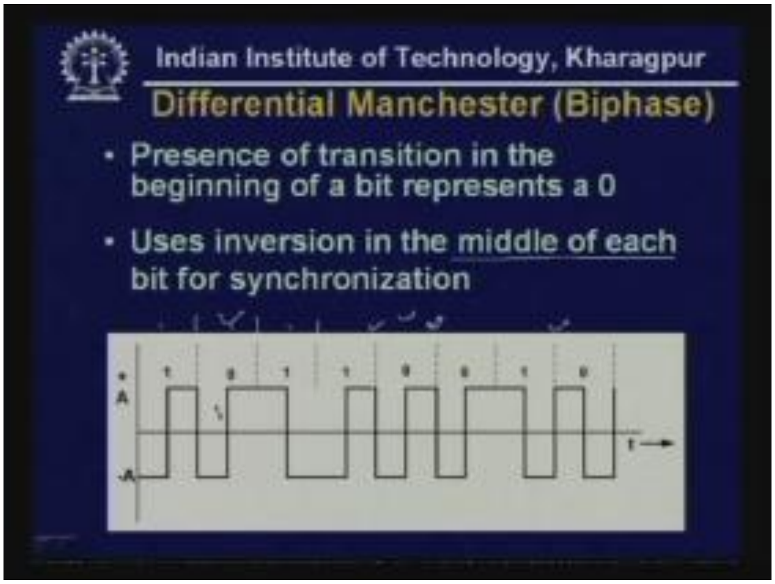

Let us see the other one the differential Manchester which is known as biphase encoding. Here the presence of transition in the beginning of a bit position represents a 1. Here this is the beginning of a bit position, this is the beginning of a position and this is a beginning of a bit position (Refer Slide Time: 31:52) if it is a 0 then there is always a transition in the beginning. For example, here there is a transition but it can be from high to low or low to high there is no distinction. If it is 1 there is no transition so it depends essentially on the previous bit.

For example, for one or 0 in the middle there will be always transition which is used for synchronization purpose. That means in the middle there is always transition. So as you can see here there is transition, here there is transition in the mid-bit position but only in the beginning there is transition if it is a 0.

So this is a 0 bit so there is transition in the beginning, this is a 0 bit there is a transition in the beginning, this is another 0 bit so there is transition in the beginning so for each of this bits so there is transition. Hence there is transition here, here, here for all the 0s and on the other hand there is transition in the middle for the purpose of synchronization. So you can easily recover data from this and at the same time it will provide you very good synchronization. So it has got two voltage level plus A and minus A as you have seen and there is no DC component.

As you can see here alternately you are making it high and low and high and low so the average value will be 0 so there will be no DC component present. It is a very good feature and it provides you very good synchronization because number of transitions per bit element will be at least one. There may be more than one transition in case of consecutive 0s or consecutive 1s but it gives you at least one transition so it gives you very good synchronization.

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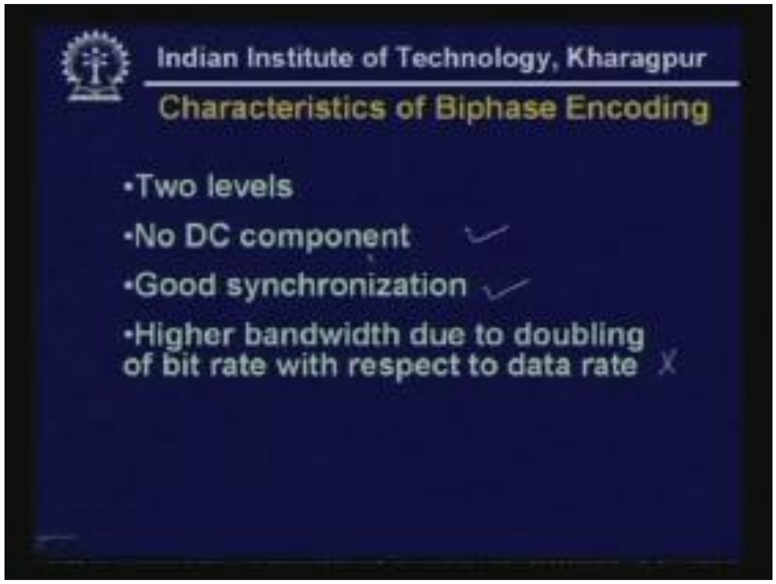

However, the bandwidth is increased here, it gives you higher bandwidth due to doubling of bit rate with respect to data rate. That means when you are sending a sequence of 0s and sequence of 1s then the bit rate is a data rate, the baud rate is double than the data rate which is a bad feature and definitely this is not advantageous. But because of these two features it is attractive and widely used in many practical encoding schemes.

Let us look at the bandwidth of these two signals Manchester encoding and differential Manchester encoding with respect to NRZ I and NRZ L.

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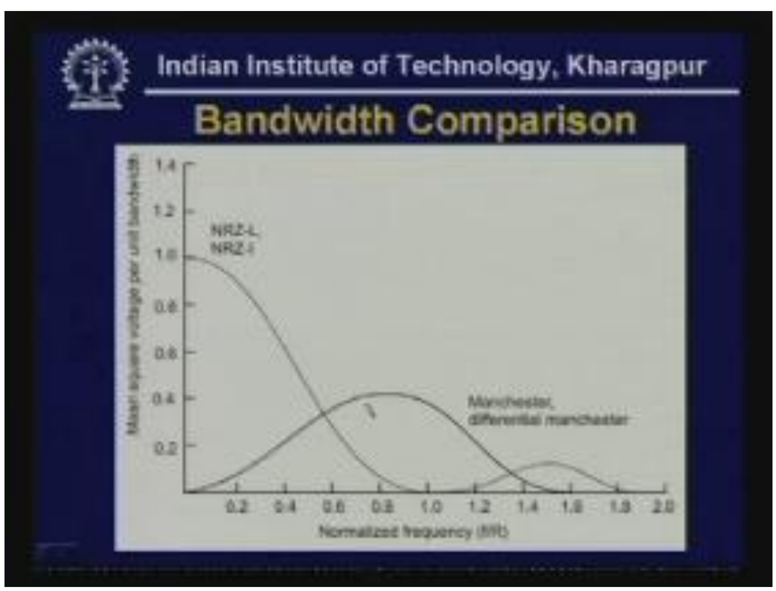

As you can see in case of NRZ I and NRZ L the bandwidth was very close to 0. On the other hand for Manchester encoding as we can see there is no DC component, there is no signal component closer to DC 0V and most of the NRZ is concentrated around the bit rate that is 1.

However, it spreads further so it can have higher frequency signal components for both the cases and it gives you some kind of bandpass which means this can be very efficiently sent through a bandpass channel because the frequency spectrum has got higher frequency components around the middle and on either side the frequency components are less. So it is a very good frequency characteristic except that the bandwidth requirement is higher.

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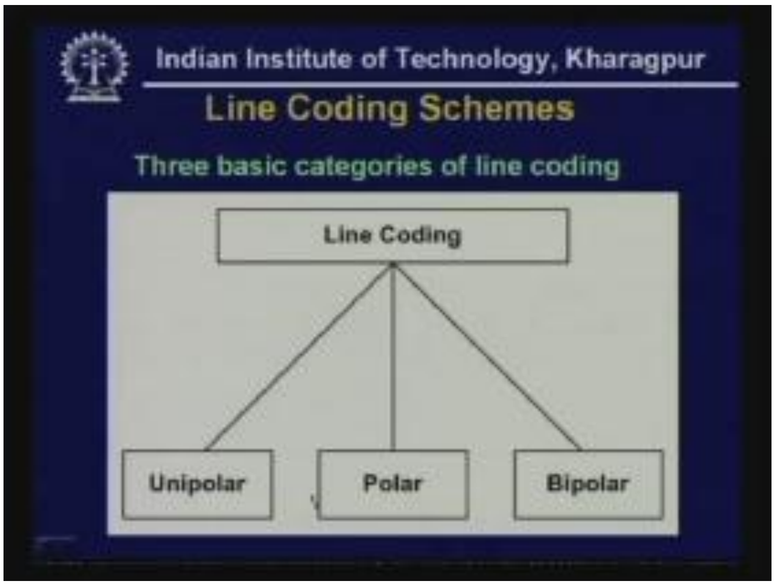

Now let us focus on the bipolar encoding schemes. We have discussed unipolar and polar and now you are considering on focusing on bipolar encoding. In bipolar encoding we shall be using a technique known as AMI - Amplitude Mark Inversion. This terminology mark has come from the day of telephony. In telephony we used to send signals in the form of mark and space so that terminology has been borrowed here and here the AMI is one kind of bipolar encoding. As we shall see this is known as bipolar AMI. It uses three voltage levels such as plus A, 0 and minus A. And unlike Return-to-Zero the 0 level is used to represent 0 here. In case of RZ encoding what we did the 0 voltage level was not representing either 0 or 1 so signal was returning to 0 both for 0 and for 1.

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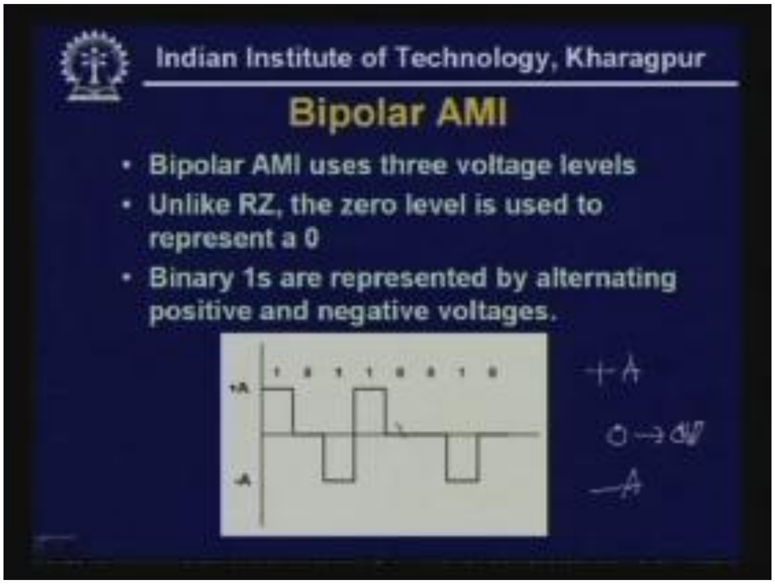

But here it is not so. The 0 is represented by, that means the 0 bit is represented by 0V. On the other hand a one can have either positive voltage or negative voltage so it alternately changes. For example, for this it is plus A, next one will have minus A, next one will have plus A, next one will have minus A so that’s why it is called alternating binary 1s or having alternating positive and negative voltages. So this alternating positive and negative voltages can be sensed to identify 1s.

However, if there is a long sequence of 0s then obviously there will be no transition so this will again lead to loss of synchronization as we shall see.

So here there is no DC component because it uses positive and negative. However loss of synchronization occurs for long sequence of 0s and as a consequence it gives you lesser bandwidth.

Somewhat similar to bipolar AMI we have got pseudoternary. It is the same as AMI but the alternating positive and negative pulses occur for binary 0 instead of binary 1. In the previous case we have seen that alternating voltages are taking place for 1. In case of pseudoternary if we replace the 1s by 0s and 0s by 1s it will be pseudoternary.

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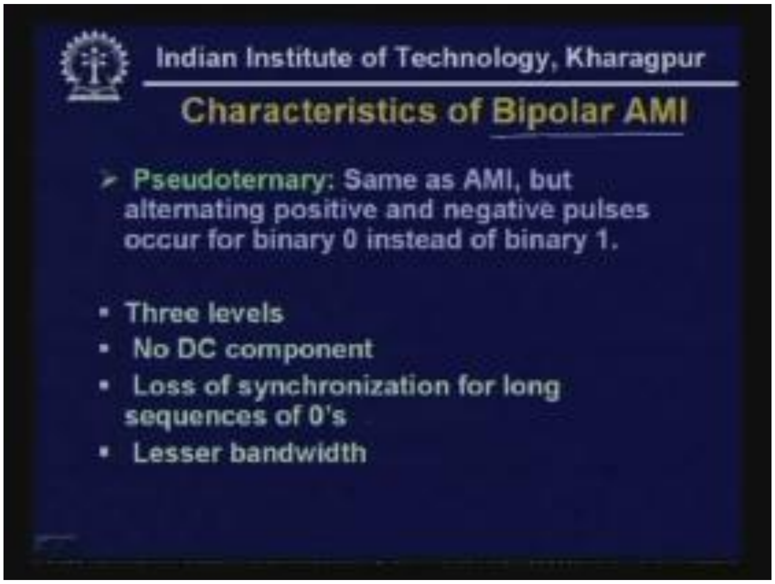

So the characteristic will be same as bipolar AMI and not different that means the characteristic will be same as the bipolar AMI for pseudoternary. But the only difference is that here binary 1 represents 0 and for 1 it is alternating positive and negative voltages. That's the difference between bipolar AMI and pseudoternary. So you can use either of the two having the same characteristics. And obviously this is a very good feature, there is no DC component, unfortunately loss of synchronization for long sequences of 0s is not useful. However, it has a very attractive feature which is lesser bandwidth as we shall see in the subsequent diagrams.

So before we compare the various techniques that we have discussed in this lecture. One important parameter I have already mentioned about it has to be taken into consideration which is the data rate and another is modulation rate.

Modulation rate is expressed in terms of baud b a u d and data rate as we know is expressed in terms of bits per second. Now what is the relationship? The relationship between data rate and baud rate is data rate d is equal to R by b where b is the number of number of bits per signal element. That means a signal element can have more than one bit, can represent more number of bits or it can have less number of bits. So depending on that the data rate can be more or less.

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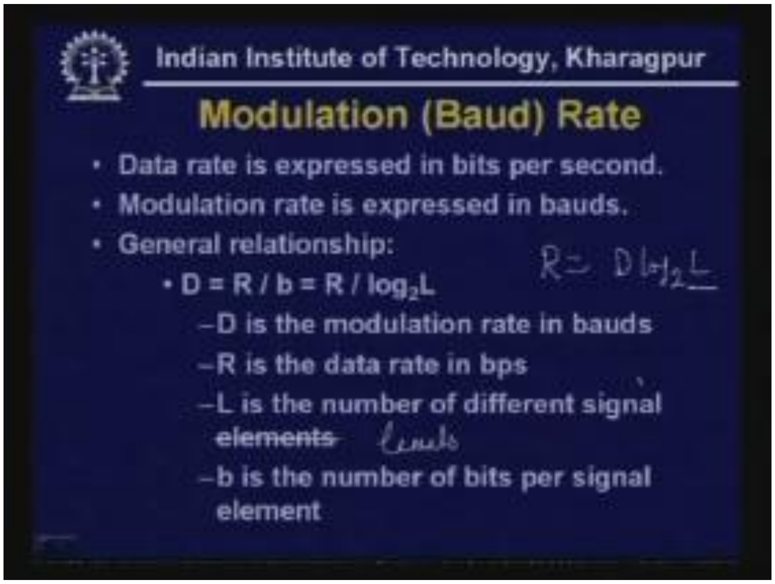

For example, if the number of levels L is the number of different signal levels that is being used then the data rate will be more than the baud rate R by b, R is the data rate that means D is the modulation rate that means R is equal to D into $\log_2 L$ that means the data rate R will be more whenever you are using more number of signal levels as we shall see. And because of this the efficiency will be more whenever your data rate is more than the baud rate.

Let us see what the situation is for the codes that we have discussed.

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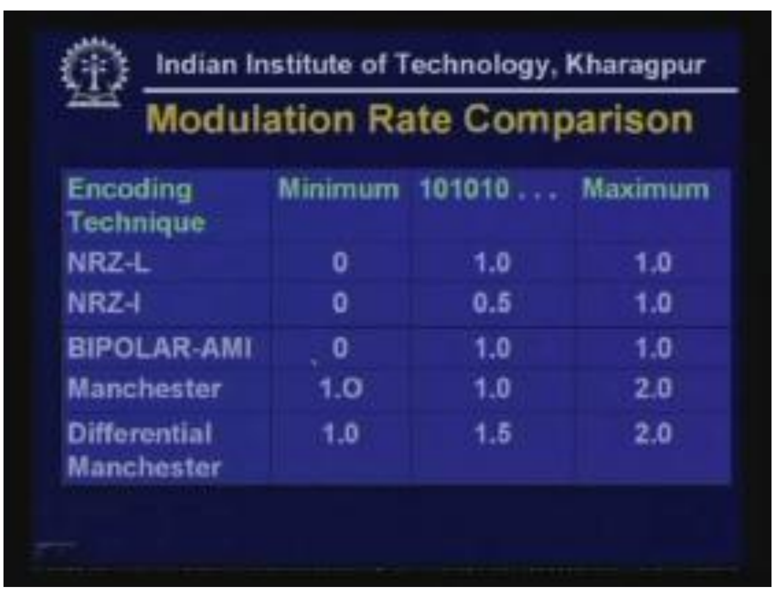

Encoding Technique	Minimum	101010 . . .	Maximum
NRZ-L	0	1.0	1.0
NRZ-I	0	0.5	1.0
BIPOLAR-AMI	0	1.0	1.0
Manchester	1.0	1.0	2.0
Differential Manchester	1.0	1.5	2.0

This is the modulation rate (Refer Slide Time: 42:00). the minimum modulation rate for NRZ L is 0 0 0 both for NRZ L NRZ I and bipolar AMI does not change at all for some values 0s and 1s so it is 0, for 1 0 1 it is alternating 1s and 0s, for NRZ L it is 1, for NRZ I it is .05 and for bipolar AMI it is 1.0, for Manchester it is 1. 0, for differential Manchester it is 1.5.

And look at the maximum, the maximum occurs in case of differential Manchester say 2.0, 2.0 both for Manchester and differential Manchester. And as you can see here from the view point of modulation rate we find that bipolar AMI has got good characteristic on the other hand the Manchester and differential Manchester requires higher modulation rate compared to the other schemes and as a result they are not very attractive from this view point.

However, we have seen that Manchester and encoding gives you very good synchronization facility. That means whenever you are sending the signal either a long sequence of 0s or long sequence of 1s it will not lead to synchronization failure because at the other end the phase locked loop will be able to regenerate the signal without any problem.

If we compare the bandwidth of the different signals we find that the NRZ L and NRZ I has got lower bandwidth. However, because of the presence of DC component and the low pass nature of the signal it is not attractive.

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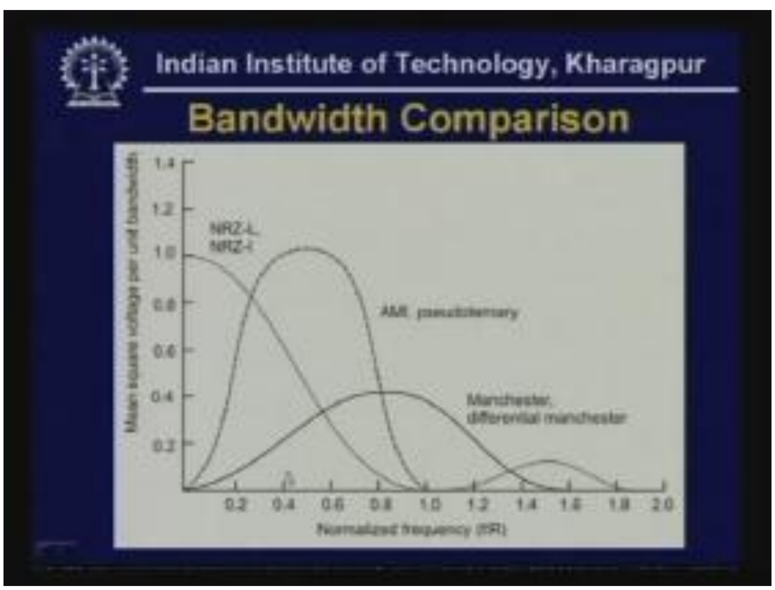

On the other hand Manchester and differential Manchester encoding has got very good bandwidth spectrum shape. It has got most of the frequency components in the middle however it has got higher bandwidth. The AMI and pseudoternary has got lesser bandwidth and it has got very good frequency spectrum and most of the energy is centered around the middle of the frequency and there is no DC component as you can see. Hence this is the bandwidth comparison of the different encoding techniques that we have discussed.

Of course there are other special purpose codes that is being used in digital transmission one is known as 2B1Q, 2 binary 1 quaternary. Compared to polar or bipolar it is four voltage levels in contrast to two voltage levels that is commonly used in polar. Here we see for 0 0 it has got minus 3V, for 1 1 it is plus 1.5V, for 0 1 it is minus 1.5V and for 1 0 it is plus 3V. So we see here it has got four voltage levels so it gives you higher data rate. That means R is equal to D if we look at the previous diagram this one that R is equal to R by b that means R is equal to D into $\log_2 L$.

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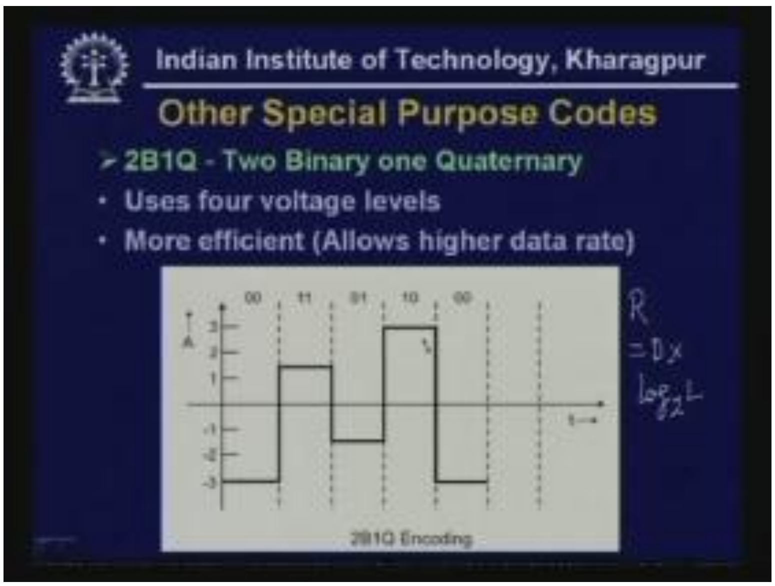

So here R is equal to D into $\log_2 L$ and L here is 4. Because it is using four levels the data rate will be two times and as a result each signal element will be able to represent two bits. Two bits means this signal element minus 3 is representing 0 0 or this signal element that is plus 1.5 is representing 1 1 so we see that by using this multilevel encoding we are able to send more data with lesser number of signal elements. In other words with lesser baud rate your data rate is more. However, because of larger number of signal levels it will be more prone to error. So signal to noise ratio of the medium has to be better only then this can be used.

Then there is another special purpose code that is used known as MTL-3 Multiline Transmission. Here also we use three levels it is very similar to NRZ I. in case of NRZ I we have seen that we are using inversions Non-Return-to-Zero inversions but instead of two levels here we are using three levels.

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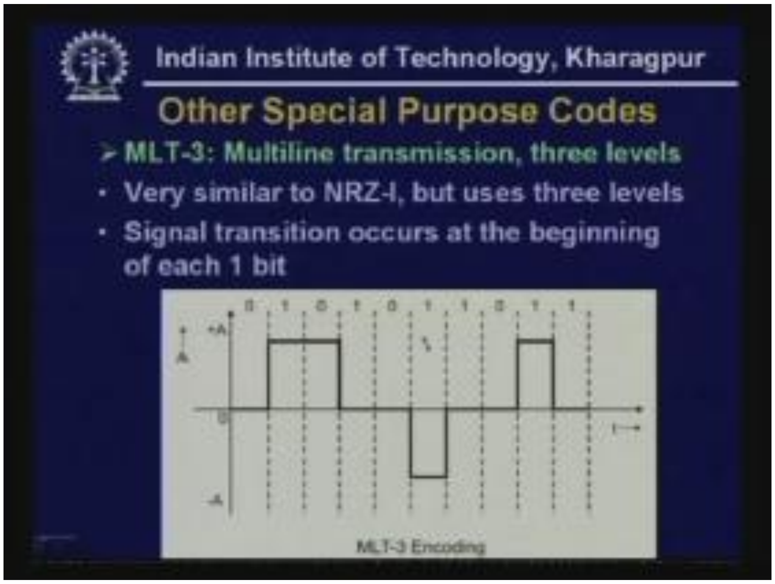

Here we see that signal transition occurs at the beginning of each one bit so whenever it is a one it is making a transition from 0 to 1 and here also it is making a transition from 1 to 0 so here we can see that we are using say 0 to plus 1 then plus 1 to 0 again from 0 to minus 1 so in this way it is using three voltage levels and signal transition is occurring at the beginning of each one. So it is very similar to NRZ I but uses three different levels that is the basic difference that is used in the beginning of each one bit that is the characteristic of this code.

Now we have seen that bipolar AMI has got very good characteristics but unfortunately it has got bad signal characteristic so the bandwidth characteristic is bad which can be improved by a technique known as scrambling scheme. This can be considered as extension of bipolar AMI. Particularly when we are sending signal over a long distance the bandwidth of the channel is very precise.

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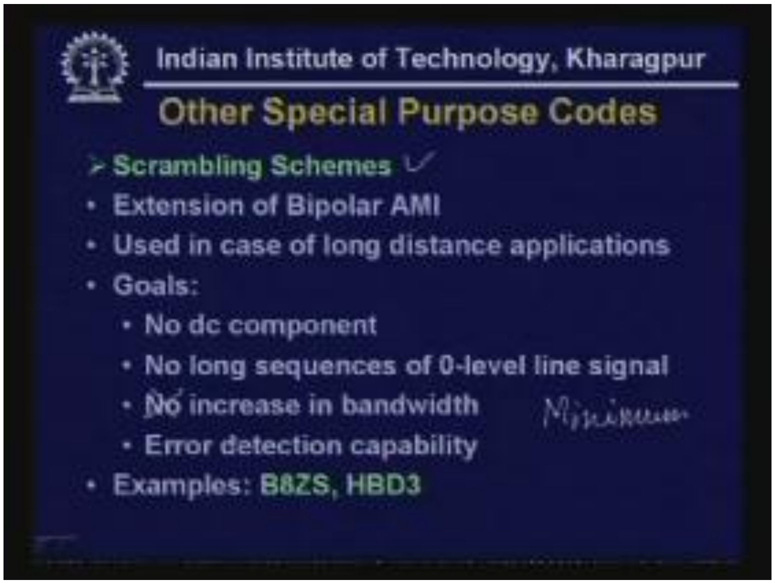

When it is for short distance communication like local area network then bandwidth is not really very important. On the other hand whenever we are sending over a long distance bandwidth has to be very judiciously utilized. In such cases we shall go for this kind of special schemes and try to develop better utilization of the bandwidth. And some of the characteristics of these special encoding codes are no DC component no long sequence of 0 level, line signal and so on. That means whenever there is long sequences of 0 level we shall try to enforcibly introduce some transition with minimum increase in bandwidth as we shall see in the next lecture.

Then it should have some error detection capability. Examples of such scrambling schemes are B8ZS and HDB3 which we shall discuss in the next lecture. So in today's lecture we have discussed about several schemes like NRZ, RZ and bipolar schemes and here are some of the review questions.

1) Why do you need encoding of data before sending over a medium?

2) What are the four possible encoding techniques give examples?

3) Between RZ and NRZ encoding techniques which requires higher bandwidth and why?

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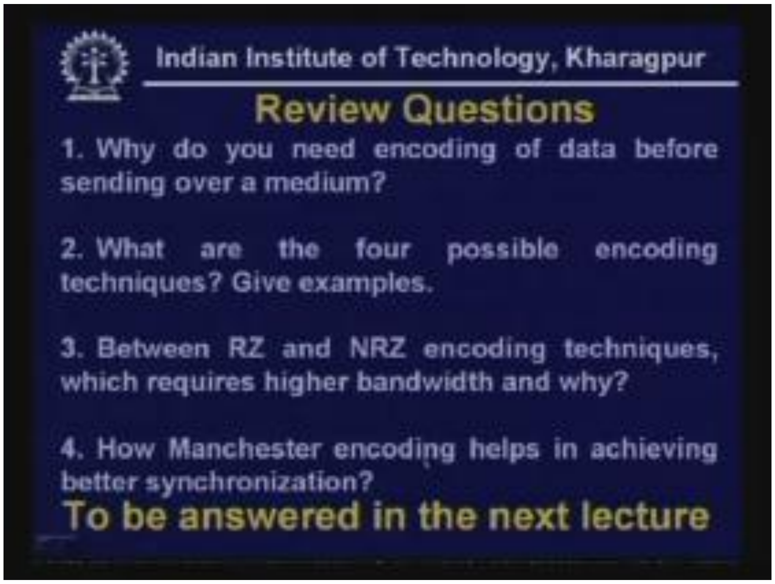

4) How Manchester encoding helps in achieving better synchronization?

Here are the answers to the questions of lecture-5.

On what parameters the quality of transmission depends in case of transmission through unguided media?

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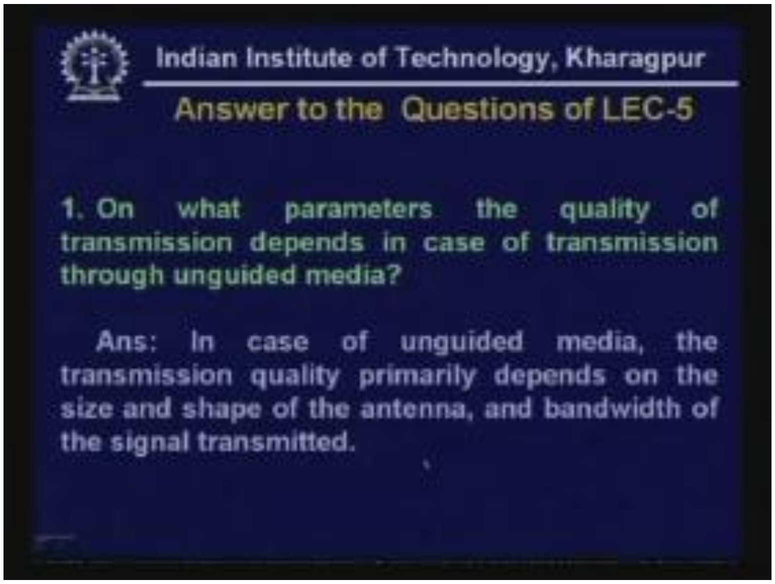

Answer is: In case of unguided media the transmission quality primarily depends on the size and shape of the antenna and the bandwidth of the signal transmitter.

So we have already discussed in detail the unguided media. There we have seen the size and shape of the antenna and the bandwidth of the signal that we are sending will play important role.

2) What are the factors responsible for attenuation in case of terrestrial microwave communication?

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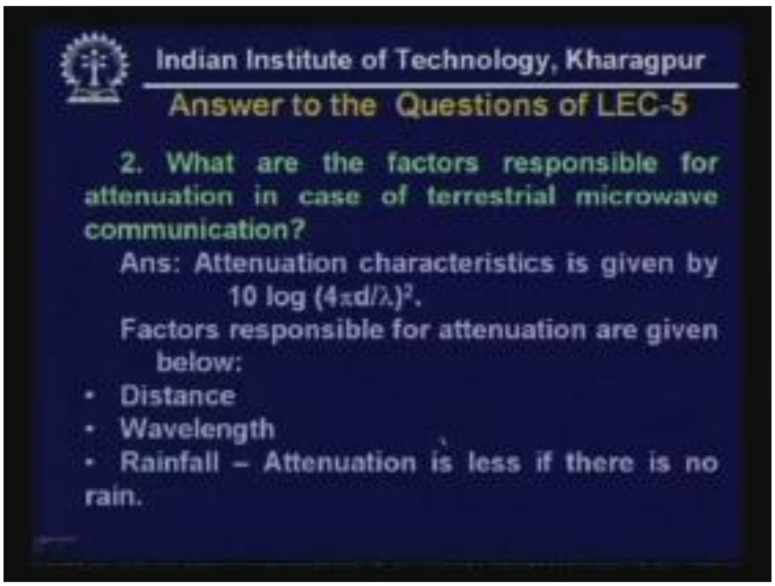

We have seen that the attenuation characteristic is represented by the formula 10 log 4 pi d by lambda square. So it depends on the distance and the attenuation increases at the rate of distance square. However, the attenuation also increases with frequency or inversely proportional to lambda square. Moreover during rainfall attenuation is less if there is no rain. So in other words when there is rain attenuation is more.

3) What parameters decide the spacing of repeaters in case of terrestrial microwave communication?

The parameters are the height of the antenna h and the adjustment factor k based on this relationship 7.14 root kh where d is the distance in kilometer between the two antennas. And based on the height of the antenna used one can calculate the distance and usually the value of k is equal to 4 by 3 that can be used to compute the distance.

4) Why two separate frequencies are used for uplink and downlink transmission in case of satellite communication

As I mentioned in the lecture two separate frequencies are used so that one cannot interfere with the other and full duplex communication is possible. If we use same frequencies then there will be interference and we cannot have full duplex communication.

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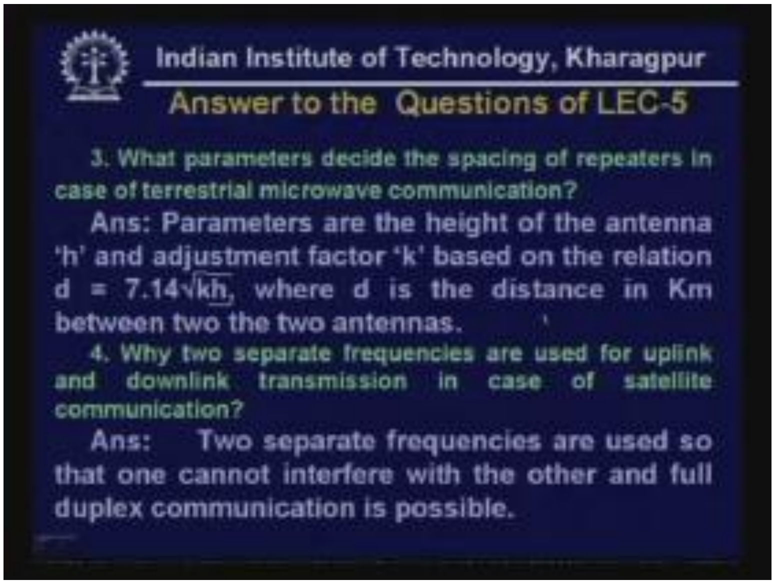

So to achieve full duplex communication two separate frequencies are used.

5) Why uplink frequencies are higher than the downlink frequencies in case of satellite communication?

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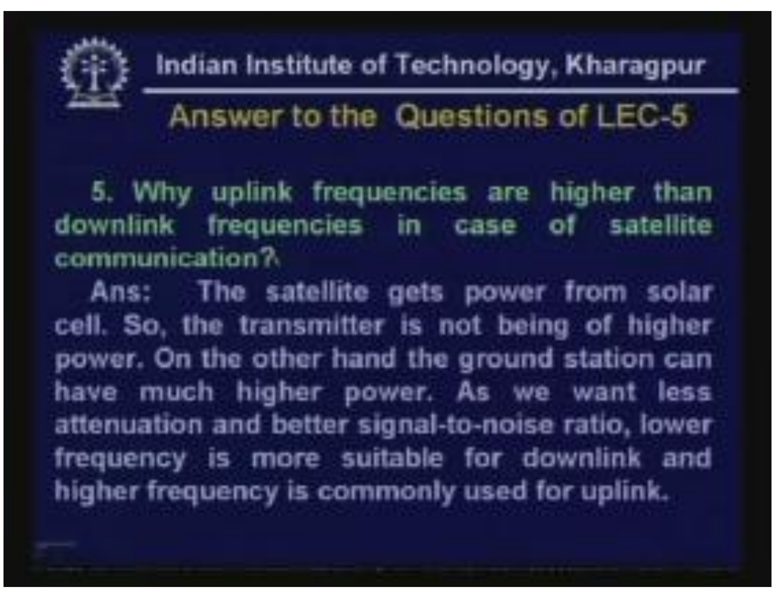

The reason I mentioned was the satellite gets power from solar cell so the transmitter is not being of higher power because it is taking power from the solar cell. On the other hand the ground station can have much higher power as we want less attenuation and data signal to noise ratio, lower frequencies are more suitable for downlink and higher frequency is commonly used for uplink. So this is the answer to the question 5 that was the last question, thank you.