Computer Networks and Internet Protocol
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Lecture - 56
Layer 1: Physical Layer – II

Hello, we will be continuing our discussion on Computer Networks and Internet Protocols. We were discussing on Physical Layer phenomenons. As I mentioned earlier that physical layer is the lowest layer in the OSI and TCP IP protocol suite. In some of the cases in physical layers are kept apart from the actual network protocols suit because of the reason that, that it is primarily more concerned about the communication between the devices or underlining media right. And as we understand that there can be different sort of consideration that can be wireless and wired and type of things and I need finally, I need a media to transfer the data from one system to another right.

Now, incidentally the mostly the mediums are mostly are carry signals through electromagnetic waves so to say and those are analogue. So, is our digital thing needs to be converted to analogue to convert that to transmit right. We have also seen that, the predominant connectivity because, this requires a physical infrastructure to be in place right, if I want to communicate across the world or across India also then I require a physical infrastructure which will work at the back bone right.

And typically the physical infrastructure which is somewhat readily available with us is our telephone network right; though the bandwidth may not be that high, but nevertheless these days with the fiber etcetera you can get higher bandwidth but, that the telephone our telephone network is the basic framework of the things.

And there are several service providers which able to which give services. So, our one consideration that if I can hook this telephone network then I can travel using this network and then at the other end get the data out of it right. So, again we are talking about the physical connects, physical layer consideration right, now in order to have this to push it to this telephone network and type of things, we have seen there is a we require a device called modulator at the at our end at that the source end. And a demodulator at the other end if the communication is this way or in other way or rather we require modem or modems at the at the devisers sets deviser sets right.

Also we have seen that we the network interface card which comes with every system to support the network connectivity is primarily have both physical and data link layer properties right. So, they have a physical layer consideration; that means, the you can connect RJ45 like our standard ethernet cables or wireless connectivity or fiber connectivity or in some cases coax connectivity etcetera right. So, these are the physical connectivity, so in other sense there should be a data link layer should be converting in them into appropriate signals to travel push the data across through the media right.

And when it travels to the media that the whatever the means consideration from the media medium comes into play it will be there right, like there could be attenuation due to noise and type of things or transmitting to a larger area a larger distance and so and so forth. So, those things will be there. So those will be there and those are consideration, it varies from medium to medium.

The things which is true for fiber are not true for not always true that particular true for cable or wireless and type of things right. So, again I just to reiterate that when we are talking about physical layer, we are considering the other layers are as there in their place. The same thing like the routing protocols works the TCP that transport layer protocols works at the suppose to work application works at they are suppose to work.

So, when you open a your email or a some network application at the upper layer the speed may vary right, due to the different type of physical wired connection, wireless connection, fiber connection and type of things speed may vary, but nevertheless the application for the application it is a communication path which is available right. So, this physical layer connectivity is the what we say that the last mile or not only that that bottom most layer of the connectivity etcetera and it dictates heavily that what should be the bandwidth, what should be the through put to some extent reliability and so and so forth.

So, this lectures what we are trying to do we are trying to look at different physical layer properties which may affect our networking capacity right. And also little bit of try to not that go into deep into the communication, but little bit of consideration of the communications which may help us understanding our systems right, so that is our consideration. So, today also we will look at some of the features and maybe in next lecture we will see some of or few more features, where the physical layer phenomenon come into picture.

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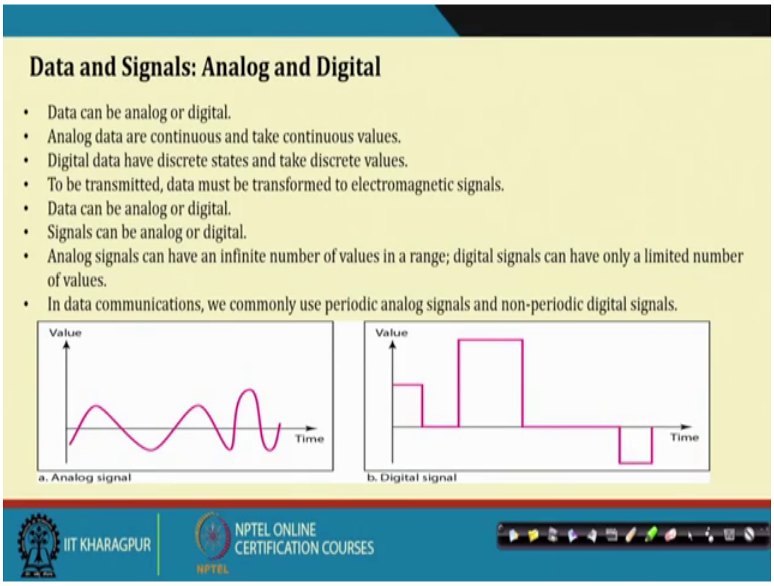

So, as we are discussing now, so 2 things coming now and then is the data and signal right. So, analogue and data and signal so what is data, what is signal and how things are going on.

So, whatever we are generating in our systems are or working with is the data which has primarily to manifestation 1 or 0 right. So, that is a binary representation of the things and I generate the data for my purpose and I do not care that how it things to be there; whereas, at the backbone as you are telling at the backbone it is primarily electromagnetic wave need to be converted to some signal. So, data can be analogue or digital, analogue data are continuous, take continuous values, digital data whereas a discrete state and take discrete values right. So, to be to transmit data must be transformed to electromagnetic signals as the media is can carry that electromagnetic signal primarily.

So, data can be as I told data analog or digital, signals also can be analog or digital right and analog signals can have infinite number of values in the range, a digital signal can have only a limited number of values within a particular range. In a data communication we commonly use periodic analog signals and non periodic digital signals right. So, it is the periodic analog signals and non periodic digital signals; that is the things which we consider mostly we will see that what are the things. So, this is a typical example of a analog signals and this is a typical scenario of a digital signal. So, we have digital things. So, I can consider that the postive has some positive voltage negative voltage, I can have different level at the positive or negative type of things.

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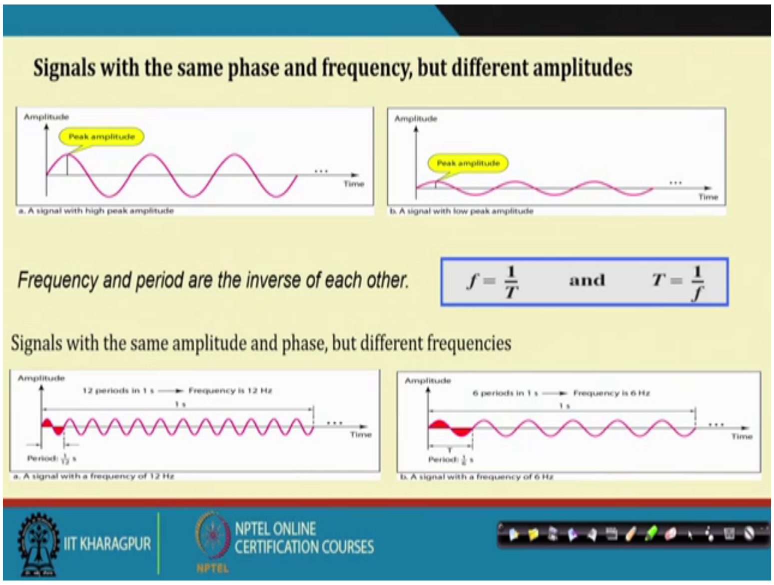

So, signals if you see what they have? They have a amplitude primarily periodic signal they have a amplitude. They have some frequency and they have a phase right. So, frequency means how what is the after what time period is returns repeats the signal whereas, the amplitude is the highest value it attains on the on the positive side or the on the negative side the minimum value it attains and the things the (Refer Time: 08:45) the amplitude of the things. And phase we will see that how much it is drifted from the origin so to say later on we will see that how things will be there, so at what time it is static.

So, signals with same phase and frequency, but different amplitudes. So, this is starting at the same time that is 0 and 0, having same frequency repeatability this and this whereas, they have different amplitude right. So, frequency and periodicity or periods are inversely proportional. So, frequency equal to 1 by T. So, it repeats f every T time durations of frequency will be 1 by T or T equal to 1 f. Signals with same amplitude and phase, but different frequency may or happens. Like this signal as repeatability is higher than this like here 6 periods in 1 second, here 12 periods in 1 second, so here frequency is typically 12 hertz here 6 hertz right, so hertz is the unit of frequency you know.

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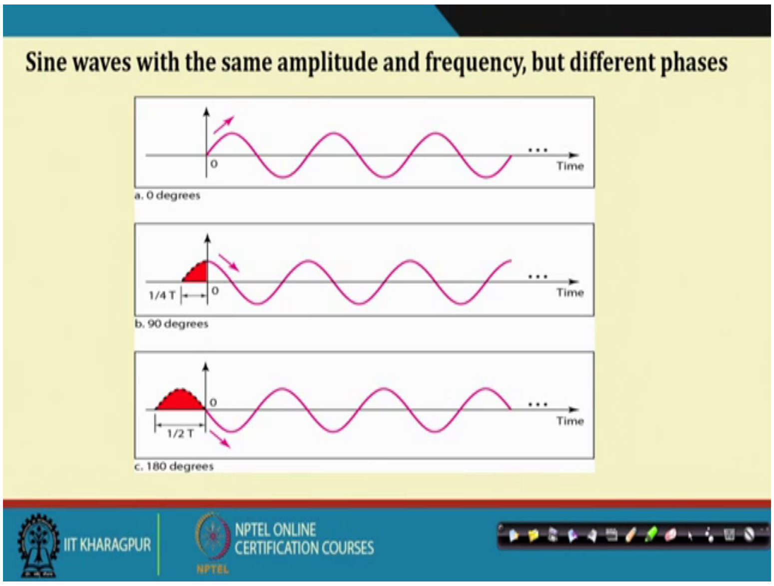

So, sine in this case, sine of the wave with same amplitude frequency, but with different phase, so it is (Refer Time: 10:01) difference stack time right. So, it is a sine wave is at different, so this is say amplitude and frequency on these 3 waves are same, but they have different stack time. So, these are the 3 thing. Now one interesting thing you see from here, so if I some way add this 3 sine wave to make a composite wave right, I have 3 waves, I have a adder or which adds. So, what does add means, that any point of time you see that what is the signal strength at 0, here it is say plus 5 or plus 10, here it is also 0, so the I in my output here I put this as a 10 if this value I if we consider as 10.

Again at this particular junction or some junction, I can basically put this vertical lines and calculate that how much value etcetera there and then some of the things and say this is my output signal because, this composite added signal right. Had it been all in the phase, same phase same amplitude etcetera the things could have gone little higher at the thing because, the same repeatability.

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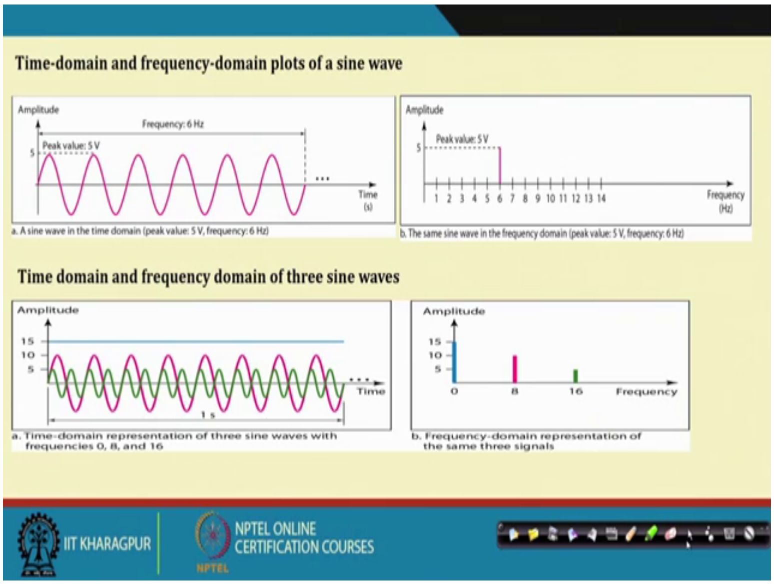

Now this way, I can have a composite signal type of things like time domain as composite signal like it may generate end up in making a composite periodic signal right, so we will see that.

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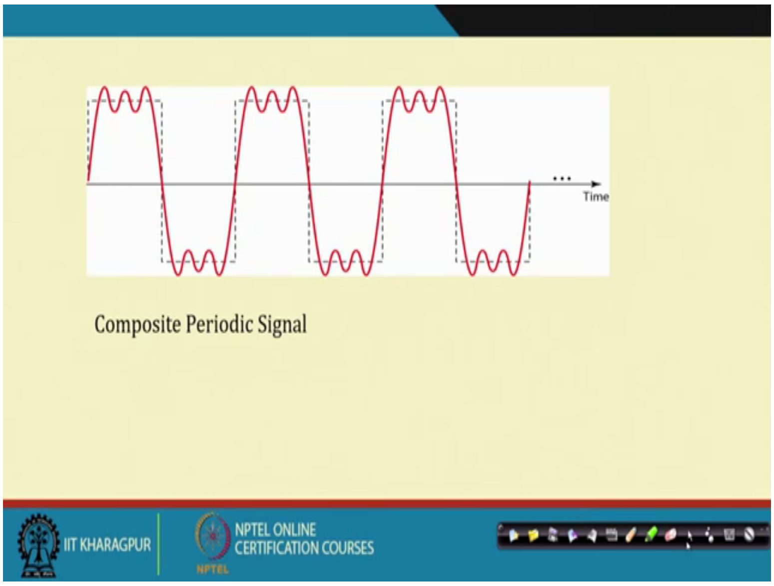

Now, we see there are 2 type of representation; the time domain and frequency domain plots of the sine wave like in this case, it is a time domain plots with time it is changing this peak value is 5 volt 5. Whereas, we can have a frequency domain thing, how many frequencies are there in here, only one frequency 6 giga 6 hertz, so it is repeatability is 6 hertz.

So, here also it is one frequency and I know that what is amplitude of the thing right, so here the amplitude of the thing. Now if I have 2 sine wave, one with a rather here we are having 3 waves, 1 with frequency 0; that is flat, one with frequency 8 and one with frequency 16, so blue, then this pink and green and then I can represent them into 3 things right like if it is a 0 frequency, there is no repeatability, so it is a dc thing, it is no not repeatable it is a constant thing and that is at 15. Whereas, frequency with 8 is that pink is at 10 and frequency with 16 that is a green is at this right.

Now, in this case again if I want to make them composite, so any point of time I go on adding what are the different values and do the composite signal right like typically I can I may have a some sort of a composite signal like this and which is again repeatable, it may not be repeatable also means it may be non periodic. But in this case periodic signals we are having because there is a inherent periodicity in the whole thing right.

So, there are in this typically if that is some half if you do in a graph paper also you can calculate. So, typically how many frequencies are there, there are 3 frequencies, if it is a sum we made it so 0 8 and 16 hertz right. So, there are a techniques like using Fourier transforms like that and we can basically (Refer Time: 13:35) composite signal is there, we can deduce it to this signal right ok. So, that is a way of representation of the things ok.

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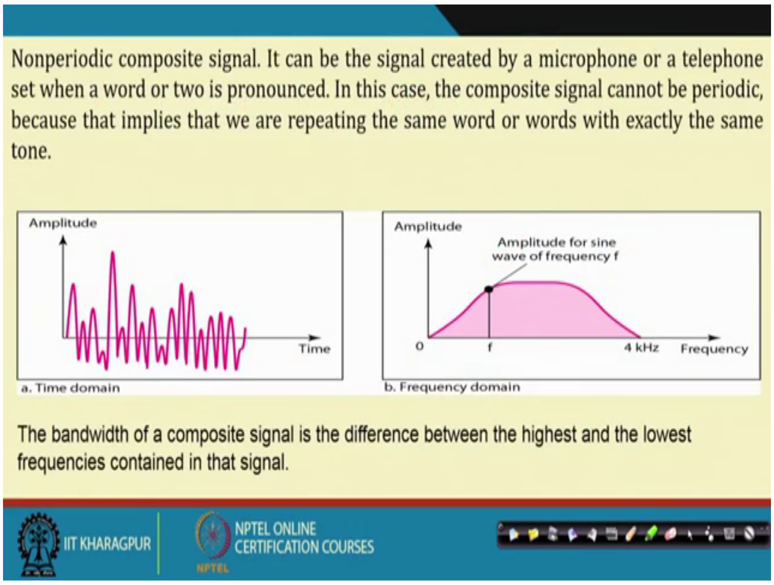

So, now we see that non periodic composite signal. It can be the signal created by a microphone or a telephone set, where the when a word or two are pronounced like, so it is I am doing analog talking with a in a microphone or telephone set. So, those things can be composite can be so, when 2 words are pronounced in this case the composite signal cannot be periodic otherwise, it is repeatability of the whole things will come up usually the conversation is a in information action. So, repeatability is much less and things are they are not periodic they are non periodic. So, bandwidth of a composite frequency difference between the highest and the lowest frequency obtained from the things.

Now, if I look at that composite frequency, it may vary from 0 that is not no signal to 4 kilohertz that is our range of vocal and type of things also that what we see that range of our telephone plane or pots telephone line is also typically in this range. So, that is the thing and I can have any frequency within this range right. So, these are this is more of a this sort of a structure I can have different frequencies at this range and it is a composite frequency.

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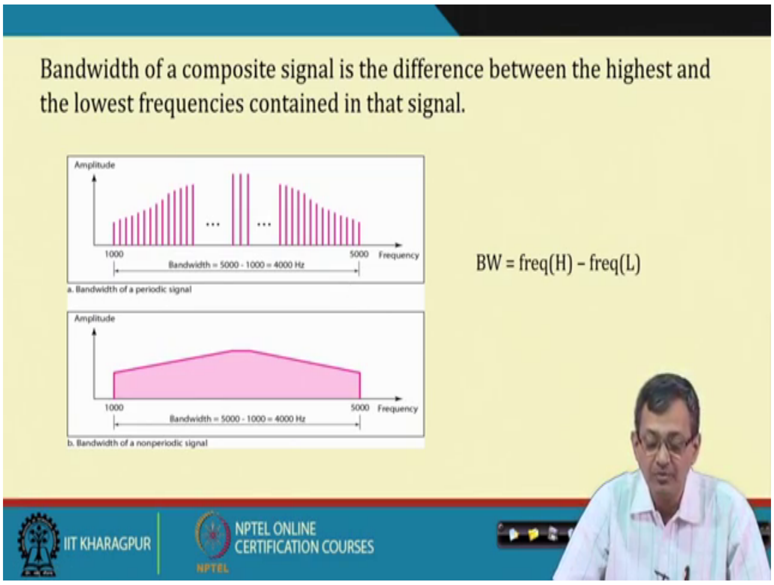

So, bandwidth of a composite signal is the difference between the highest and the lowest frequency of the thing right. So, it is bandwidth is given by the highest and the lowest frequency for that matter in a signal the highest frequency and lowest frequency is the magnitude of the things right. Why we are breaking our heads on this, because your communication channel may not allow all frequency batch right. So, it has a own property right, it has own materialistic material property and then based on that all frequencies may not be allowed. So, it may allow a set of frequency, if it is some of the channels may allow in wider range, it may be allowing this range of frequencies in the things.

So, your data signal or the data which you are generating at the at the end points, should be able to put through this channel only right or I need to know that how much the channel can allow and capacity type of things right. So, that is why we need to study that how is this type of bandwidth consideration those are coming up in terms of this signaling or communication.

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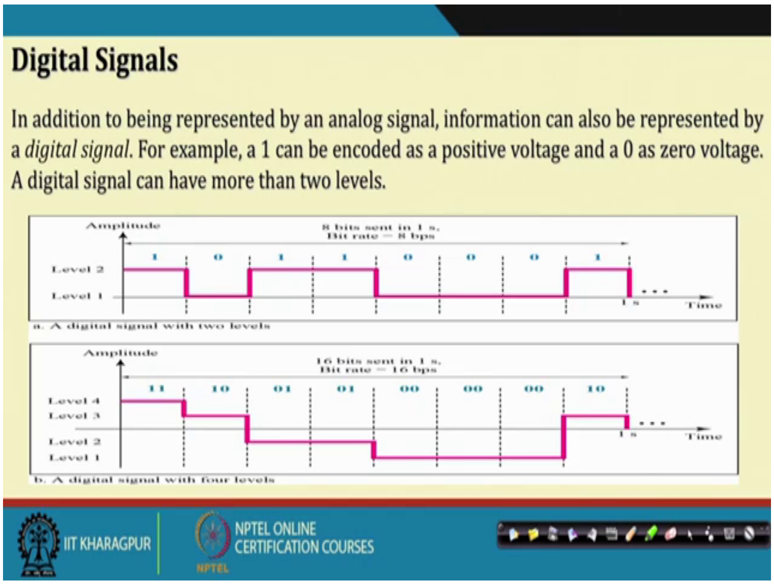

Now, if you come to the digital signal it addition to being represented by a analog signal, information can all be also be represented by a digital signal; for example, one can encoded as a positive voltage, 0 can be encoded as a means as a 0 voltage, so I can have 0 and 1 digital signal can have more than 2 levels, even it can have 2 levels, 1 is here it is only 2 levels right with 1 and 0. It can have more than more than two levels right different levels, so I can have 1 1 1 0 0 1 1 0 0 0 and type of things right.

So, this is more than 2 levels that the more data is packed within the thing right. So, in a effectively I can make more data communicate within that pack thing. So, it gives us a better output right, but not always feasible we will see.

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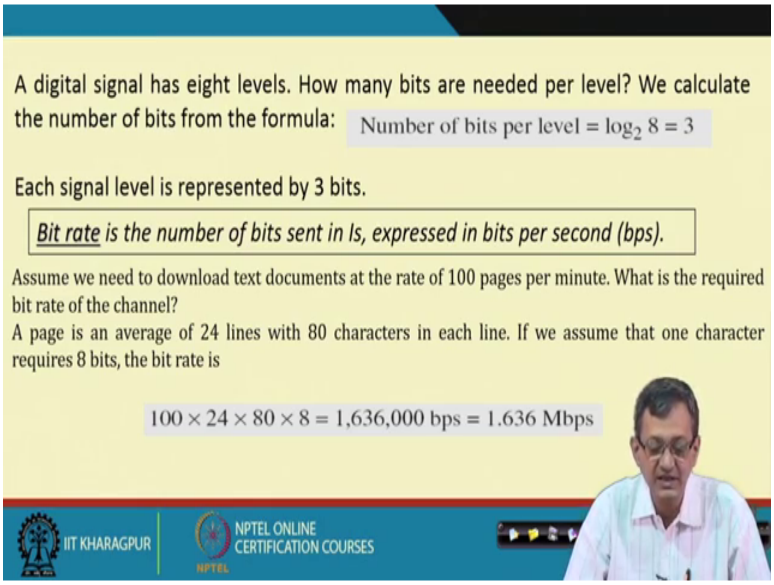

So, a digital signal has 8 level, how many bits are needed per level. We can calculate the bits as with a formula that log 2 8 equal to 3 bits. So, if it is eight level so I can have 3 bits 2 to the power 3 is 8 right. Each signal level is represented by 3 bits. So, bit rate is the number of bits, since in one second expressed in bits per second right. So, assume we need to download the text documents at the rate 100 pages per minute. So, if that is my consideration what is the required bit rate of the channel so, if the page is an average of 24 lines with 80 characters each line, we assume that one character requires 8 bit representation. The bit rate is 100 into 8 into 80 into 8 equal to 1 point so that is 1.63 mbps. So, that is the bit rate for this type of things right.

So, it is a very flat way of calculation, there will be lot of other consideration, but nevertheless we can have a come to a thing.

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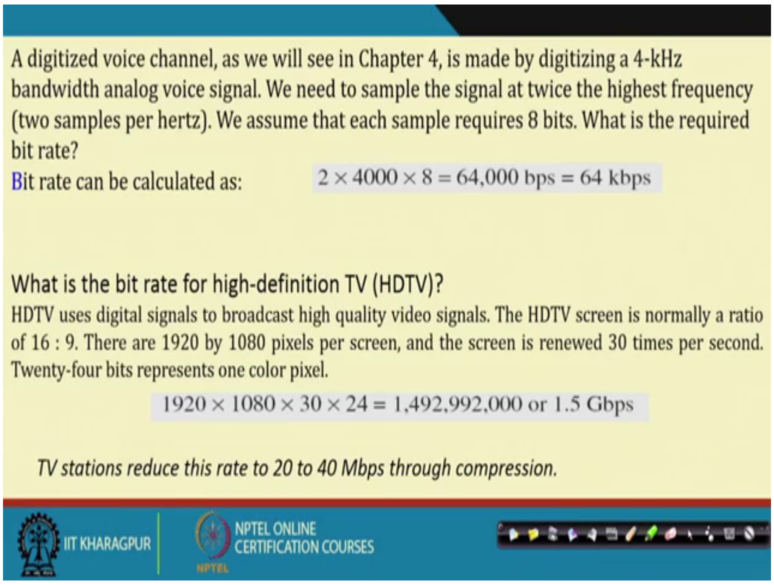

Similarly, a digitized voice as we see in somewhere it is digitized at a 4 kilohertz and we need to sample the twice the highest frequency then we can have a bit rate. Similarly what is the bit rate of http, we can calculate with the rate of what is the reference time and so and so forth.

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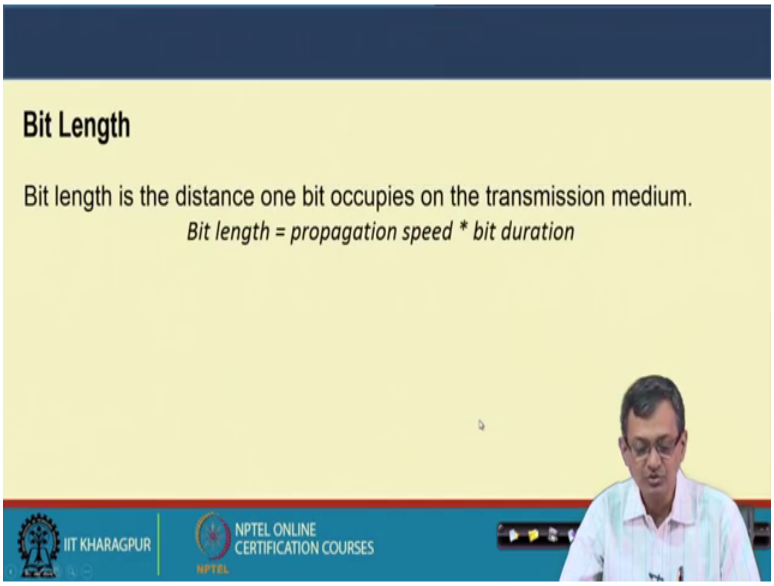

So, this way I can calculate the bit rate. There is a concept of bit length, the bit length is the distance of 1 bit occupies in the transmission medium right. So, bit length is the distance 1 bit occupies in a transmission medium. So, bit length equal to propagation delay into bit duration, so how much duration is there along with the propagation speed is give me the bit length.

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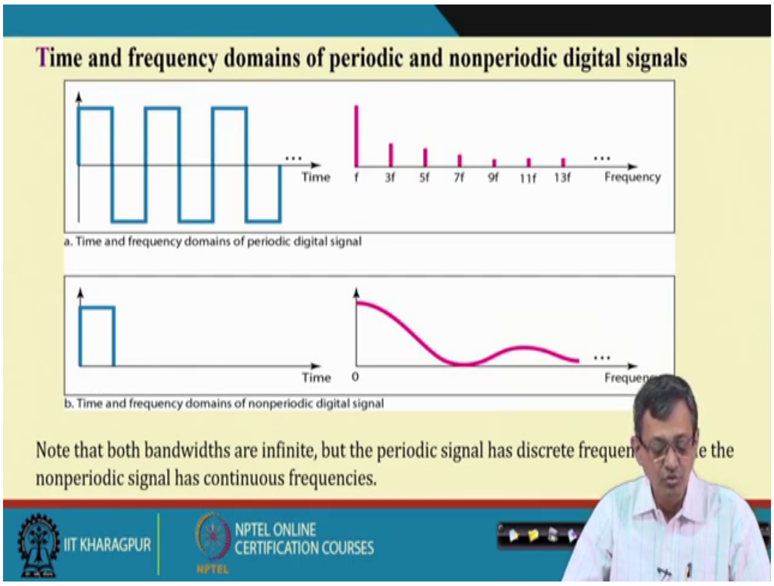

So, time and frequency domain periodic and non periodic digital signal, so this is the representation of this if I have a periodic signal and if you have a non periodic digital signal then the frequencies are both actually, both cases it goes to infinity right, so end of the things. But in order to reconstruction I may not require those frequencies which contribute very less into the things right. So, there are different consideration from the communication point of view, there are consideration like take that which harmonics of the things will be there or harmonics and type of thing, how many you can go to gave effectful reconstruction. So, both bandwidths are infinite, but the periodic signals has discrete frequencies, which referred as the non periodic signal has continuous frequency right.

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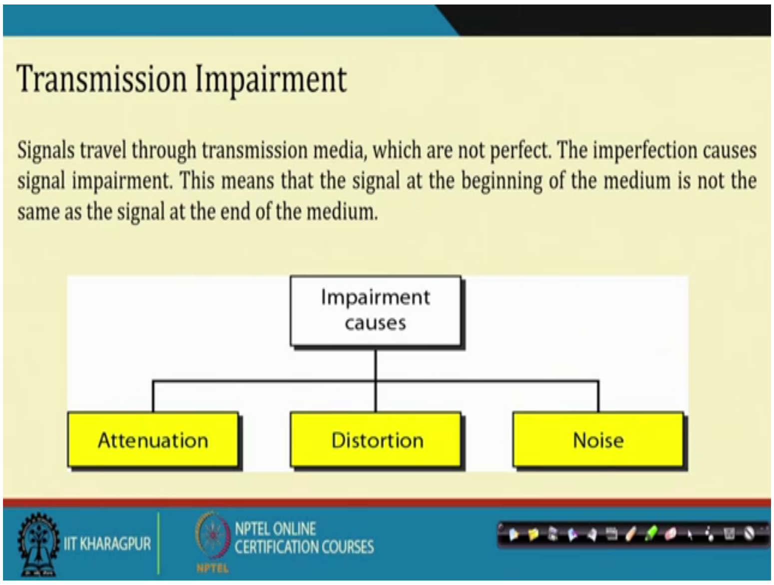

So, there is another consideration comes out when we try to transmit data over a channel right, what we say it is a transmission impairment right. Signal travel through transmission media which are not perfect, the imperfection cause signal impairment right. This means that the signal at the beginning of the media is not at the same other things. So, you send something and it is something got in not the same thing. The typically 3 categories of things are there, one is the attenuation, one is distortion, another is the noise. So, this type of 3 type of situations which causes this term impairment.

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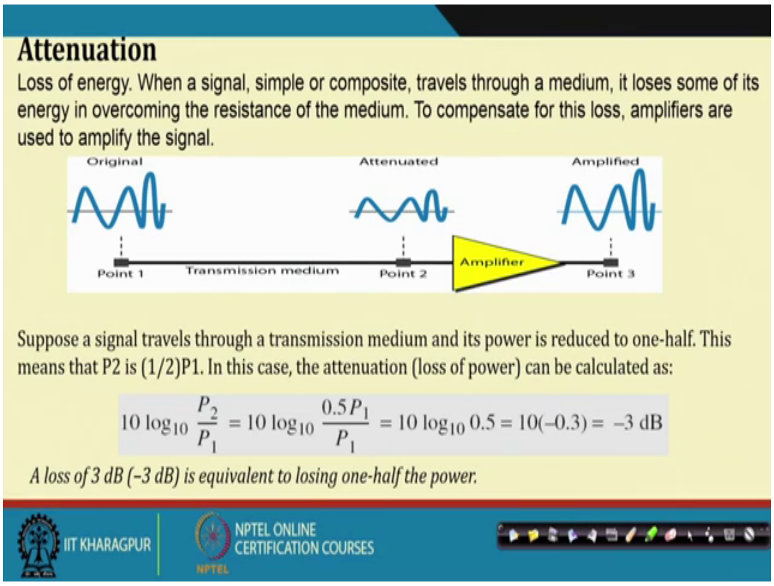

In case of attenuation loss of energy, when the signal and the simple or composite travel through the media, it losses some of its energy in the in overcoming the resistance of the media. To compensate this loss the amplifier are used to or signal regenerator I used to say instead of amplifier are used to regenerate the signal right, so it has the degrader a regenerator.

Suppose a signal travels through a transmission media and its power is reduced to half. So, it was P and now it is P by 2 or sorry P1 and now P2 is half of P1. In this case, the attenuation loss power can be calculated as like this right. So, a loss of 3 db or minus 3 db is equivalent of losing half of the power. That is why that that 3 db loss etcetera we coming to play that is a 50 percent power is lost.

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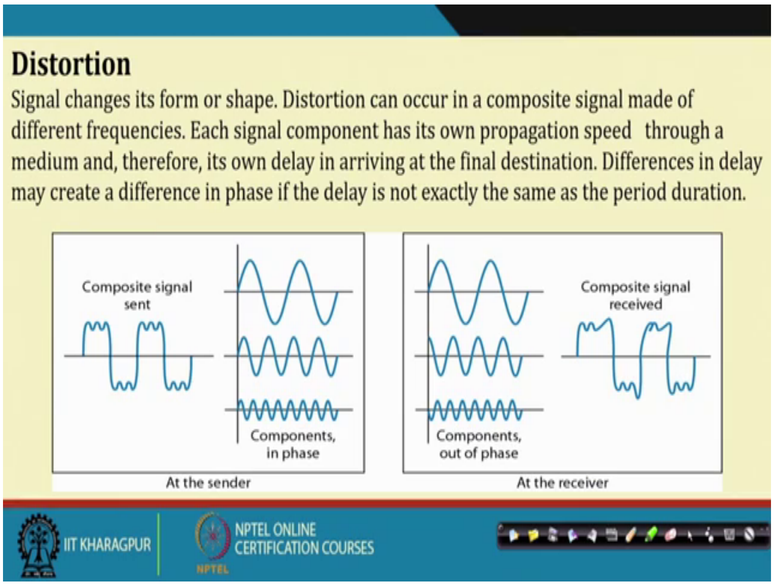

Another means another source of impairment is that distortion, signal changes its form or shape right. Distortion can occur in composite signal made of different frequencies. So, each what happened each signal component has its own propagation speed through a medium and therefore, its own delay arriving at the destination.

So, differences in the delay is create a difference in the phase which in turns not exactly the same of the periodic periodicity of the periodic duration. So, let us see, I send a composite signal which has number of frequency component incidentally, because of this channel characteristics that is the channel properties the different frequencies get different type of say delayed of reaching the things. So, there are no attenuation per

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So, when you reconstruct you cannot reconstruct the same composite signal or in other sense you do not get back the same data. So, it if it is a here you see it was in phase data like this is same time in phase data when we made a composite signal due to impairment it receive there you decompose the signal it goes for a impairment like there is a shift here with respect to this. So, there is a phase shifting we will go for a problem of the overall data.

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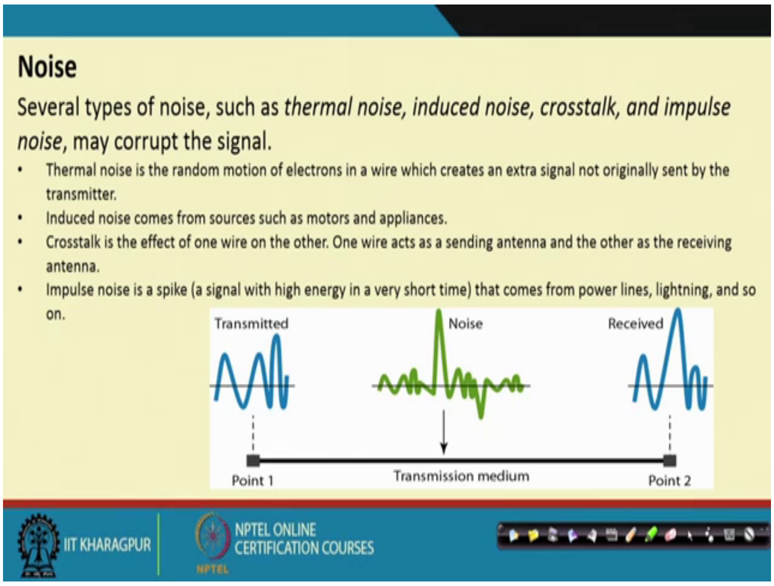

And finally, we have this noise as the impairment right. Several type of noise such as thermal noise, induced noise, crosstalk impulse noise may corrupt the signal right, so there can be different noise. So, thermal noise is a random motion of electrons in wire which creates an extra signal not originally sent by the transmitter. So, that it is the thermal noise. Induced noise comes from source, such as motor or appliances from different source has induced no, so that is induced in the thing.

Crosstalk is the effect of 1 wire on the other, 1 wire acts as a sending antenna other as the receiving antenna. So it is a crosstalk when two things are moving, a two things are in nearby location and there can be impulse noise is a spike signal with very high frequency with very short time that comes from the power lines lightning etcetera. So, there is a impulse and the impulse noise.

So, these are the different category of noise which distorts or creates problem in the signal right. So, in other sense there are impairment and there is there will be a challenge in reconstructing the things. So, what we see, this noise also plays a important role in faithful delivery of the signal at the other end. Now these are the things which are there right, we need to with respective this we need to send data and type of things.

So, there is 1 1 side there are lot of development or things are going on that, how more improved channels can be created like, you get a more faithful transmission when you do you work with something called in fiber type of channels and type of and then other things that whether, I can better way encode or modulate the data. So, that the, so it can be sent through even to some extent not so good channels and type of things.

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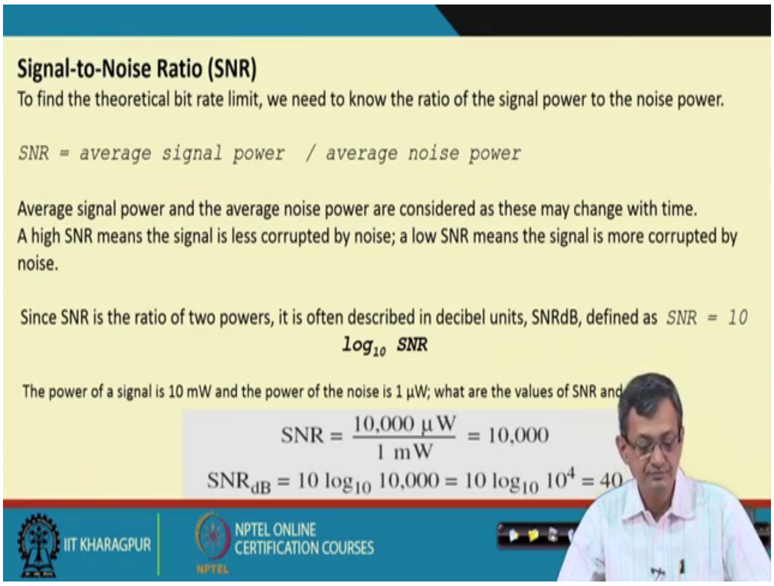

Another metric come into play or we listen now and then is a signal to noise ratio. To find the theoretical bit rate, we need to know the ratio of the signal power to the noise power. So, average signal power by average noise power that is important, so get the SNR type of thing. So, average signal and average noise power are considered as these may change with time right. A high SNR means the signal is less corrupted by the noise or a low SNR means the signal is more corrupted by noise. So, this is the consideration means that that plays a important role right. Since SNR is the ratio of 2 powers, it is often described in decibel and SNR dB defined as SNR equal to 10. So, there is a typo at

10 log 10 SNR, so it should have been in the same line. So, similarly I can calculate a SNR and SNR dB using this right.

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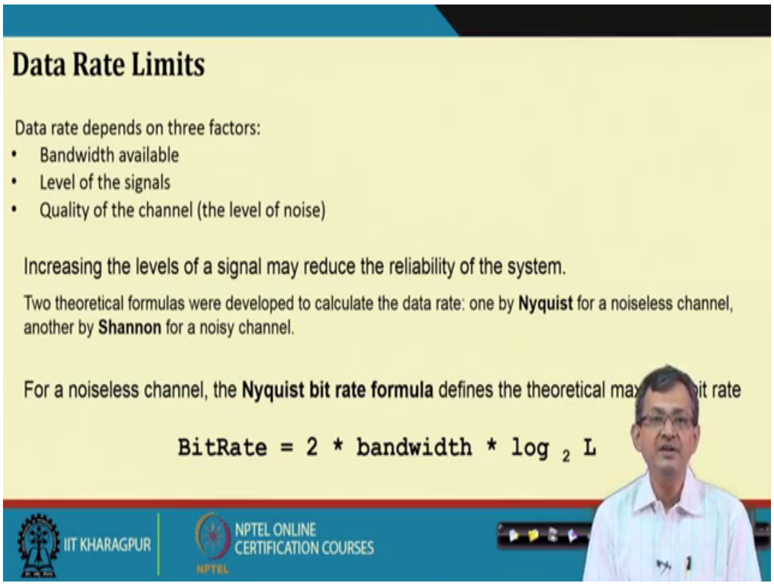

Data rate limits. So, data rate depends on primarily one 3 factors; one is the bandwidth available how much bandwidth you are available. Level of signals, what are the levels of signals it is a 2 level, 4 level what are the levels of signals. And quality of the channel level of noise right. So, what is the quality of the channel right like, the fiber some fiber cable there will be a different quality aspect then if you have a watt cable and type of things. So, quality of the channel or the level of noise plays a important role.

Increasing the level of the signal may reduce the availability reliability of the system. So, if I go on increasing the level of the signal because, we say that if I go on increasing the thing it is more compact and I can (Refer Time: 27:32) but it hurts the reliability of the things, more granular things more finer things there will be more likely chance of disruption or distortion and type of things.

So, there are 2 theoretical formulas which help us in estimating that what should be my bit rate and type of things. So, one is Nyquist for noiseless channel, another is Shannon proposed by Shannon for noisy channel. So, we just see quickly that what they say the Nyquist bit rate formula defines the theoretical maximum bit rate is the 2 into bandwidth into log 2 base 2 L is the number of levels right. So, there is that is the theoretical thing in a noiseless channel.

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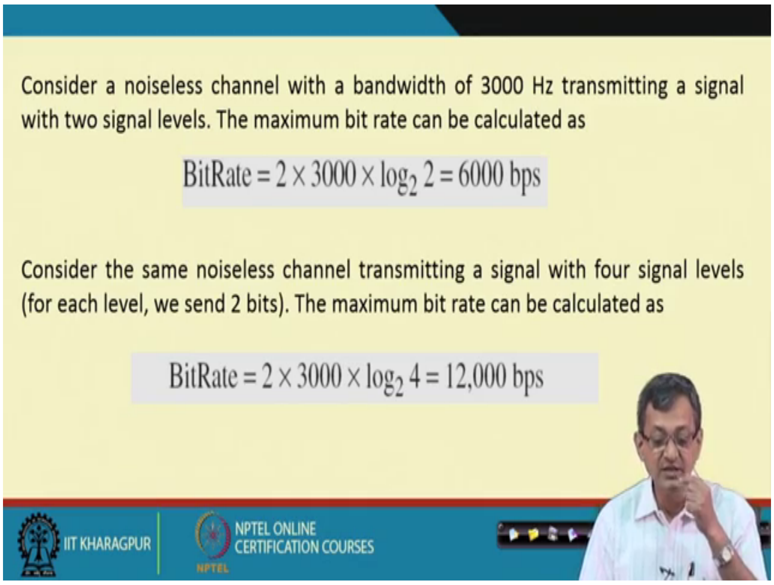

So, consider the noiseless channel with bandwidth three 100 hertz transmitting a signal with 2 signal level. The maximum bit level can be calculated as 2 into 3000 into log 2 base 2 equal to 6000 right.

Consider the same channel transmitting a signal with four signal level. So, instead of one it has a four signal levels. So, what it goes on, it basically say 2 into this it should be 12000 bps. So, changing the signal level, I can go up in the bandwidth right.

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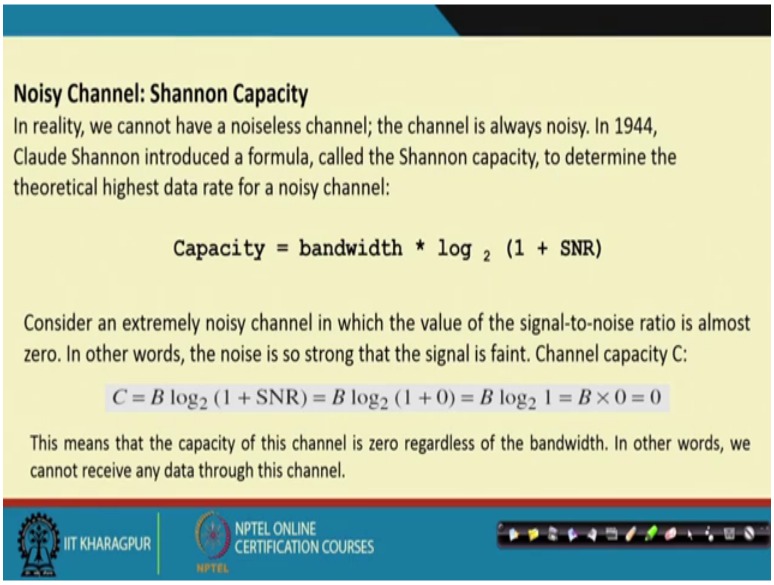

So, for noisy channel that we have that Shannon's capacity, in reality we cannot have noiseless channel right, so there will be some form of noise or not the channel is always noisy. In long back in 1944, the Shannon introduced a formula for Shannon capacity to determine the theoretical highest data rate for the noisy channel. So, what is the highest data rate it can support, so bandwidth into log base 2 1 plus SNR that is the highest. (Refer Time: 29:24).

Like consider an extremely noisy channel in which the value of the noise to signal to noise ratio is almost 0 right. So, that is all you made number of levels etcetera, but the noise is so high, the SNR value is nearing 0 right, so very low signal. Say, channel capacity C equal to B log 2 1 by SNR and then what we can find out that irrespective of what whatever you do finally, it end ups with the 0 only a 0 there is no transmission is possible, so much noise is there.

This means the capacity of the channel is 0 regardless of the bandwidth in other words we cannot retrieve any data through this channel right. So, this is the way it gives some limitation of the means boundary of the things that what is the highest level you can reach with this type of channel and type of things.

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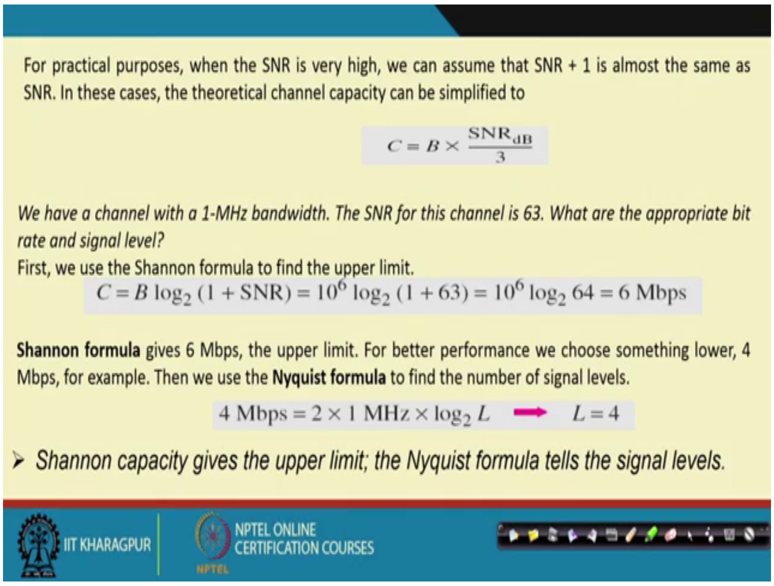

So, if you see for practical purpose when SNR is very high, there is we assume that the SNR plus 1 is also almost the same like if you have a huge SNR. So, practically 1 plus SNR is same or in other sense, the theoretical channel capacity can be expressed as C equal to B into SNR dB by 3 right, so based on the things. We have a channel with 1 megahertz bandwidth, the SNR of this channel is 63, what are the appropriate bit rate and signal levels? Correct so, this is the thing we want to find out.

Like first we use Shannon s formula to find out the upper limit right. So, it is B log 2 1 plus SNR and something 6 mbps, so that is the upper limit. Now the upper limit the better performance we choose something lower that is 4 mbps for example, and use the Nyquist formula to find out the level. So, putting the Nyquist formula we found out the level equal to 4.

So, somehow means if we try to look at the summarize the thing, so what we use the Shannon capacity gives us the upper limit, the Nyquist formula give us the signal channel. Now see our this basic consideration helps us in finding the what could be my channel capacity, what amount of rate we can get, this may allow me to plan something that what should be the data transmission time etcetera and type of things right that, which is very much needed for different consideration.

So, let us with this thing that basic fundamental way calculation that and this digital signal digital data and signal and analog data and signals considerations, how we can have some sort of estimate of approximate bit rate and the signal levels that will we have seen and this will help us in estimating separate thing. So, with this let us conclude today, we will be continuing our discussion in our next lecture next lecture on this physical layer.

Thank you.