Fiber Optics

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Lecture - 02
Need for Optical Communication

Today we will understand why do we need optical waves for telecommunication, what is wrong with copper wire communication or what are the limitations of microwave link so that we require this optical communication. To understand that let us first understand the communication itself, when I speak to students in a classroom I just speak and they listen this is a communication I deliver my lecture. But the students which are sitting in the next room cannot listen to me. So, what I need to do is if I want them also to listen, I convert my voice signal using a transducer into electric signal and take that electric signal through copper wire to the next room. And in next room I convert that electric signal into voice signal again using for example, a speaker in this way I can communicate to them.

But if this, the next room is not very near if I want to send my voice signal to a very distant room, then of then what I will do? Well I will do the same thing, but perhaps I will put an amplifier in between, but if I want to communicate to somebody who is sitting in the, we sitting in some other city then I cannot do it like this, this way of communication is limited only to very small distance, and in this way only one person can communicate at a time. I cannot carry out several communications simultaneously using this kind of setup.

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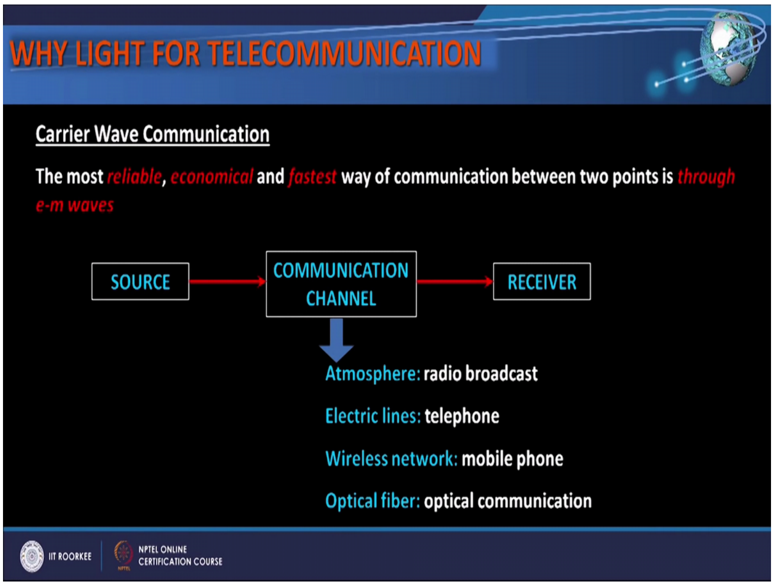

So, what is done well the communication is then done through electromagnetic waves, the most reliable economic and fastest way of communication between two points is the communication through electromagnetic waves. And in this kind of system we have three major components, the source, the communication channel and the receiver. This communication channel can be atmosphere for radio broadcast, electric lines for telephone, wireless net board wireless network for mobile phone and optical fiber for optical communication. This communication channel introduces loss and distortion to the signal.

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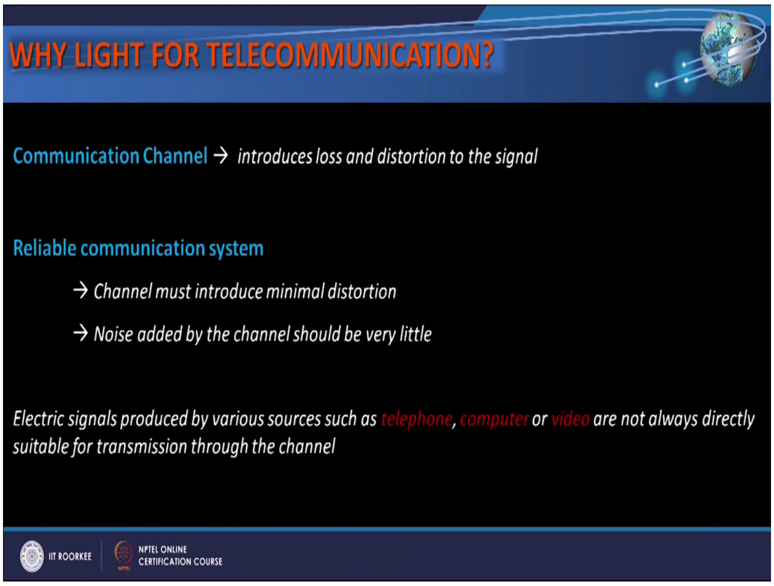

And for a reliable communication system what do you require is that, the distortion introduced by the channel should be minimum, and the noise added by the channel should be as little as possible.

The electrical signal which is produced by various sources such as telephone computer video there are not always directly suitable for transmission through this communication channel, if you want to do several communications at a time. Then what you do basically you use this signals to modulate high frequency electromagnetic wave.

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This high frequency electromagnetic wave can be a radio wave a microwave or light wave. And these kinds of waves are called carrier waves. So, this modulated e m wave carries the information, and this kind of communication is known as carrier wave communication.

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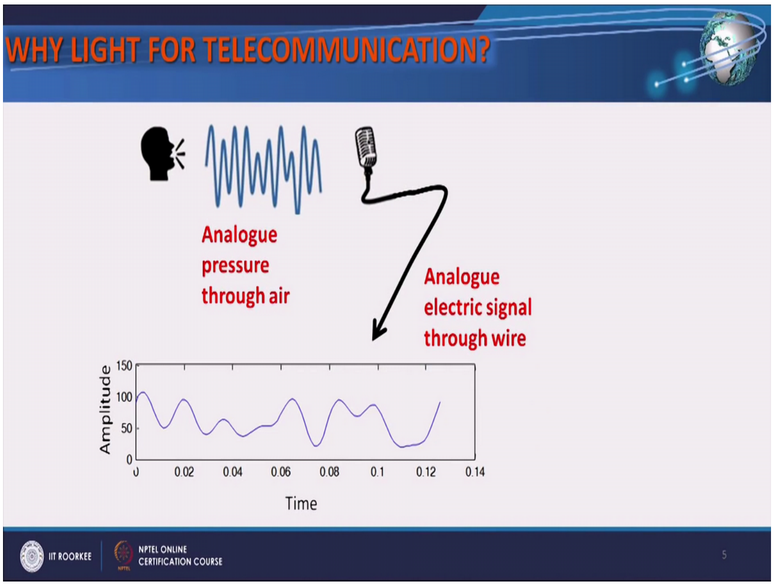

So, here is a typical setup when you speak, there is analogue pressure generated through air and if you put a microphone this gets converted into electric signal. If you monitor the amplitude of this electric signal over time, it may look like this which naturally contains several frequency when I speak it is not a single frequency. It contains large number of frequencies and that is why this looks like this, it is not a harmonic wave.

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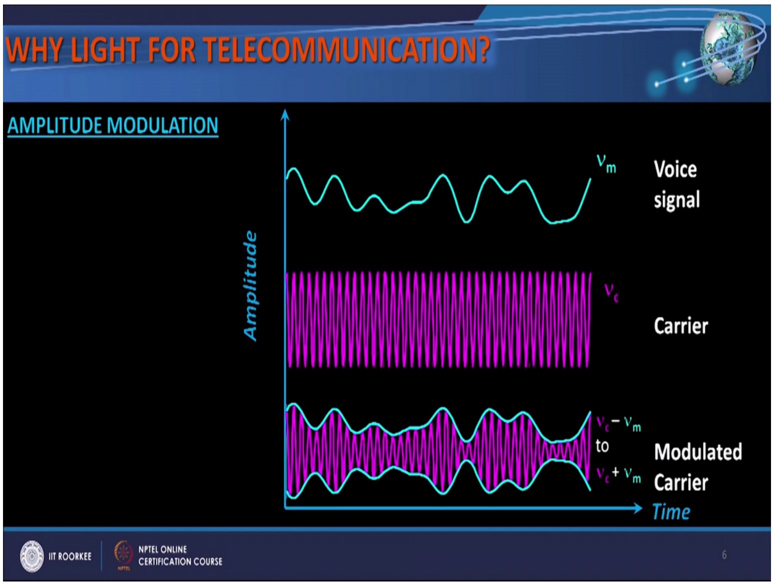

So, if I want to understand this carrier wave communication, then the easiest way is that I model at the amplitude of the carrier wave using the voice signal, and when I do that then the modulated carrier looks like this the envelope of the carrier wave now changes in accordance with the amplitude of the voice signal, this is known as amplitude modulation.

Now, if new m is the maximum frequency of the voice signal, voice signal has several frequencies. So, I find out what is the maximum frequency they are if it is new m and new c is the frequency of carrier wave, carrier wave is harmonic you can see it is perfectly harmonic wave. Then the modulated carrier wave will have frequencies ranging from new c minus new m to new c plus new m, it is not a single frequency anymore it is got a range of frequencies.

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Now, if I want to transmit this is speech signal, then what I do? I make use of the fact that this speech signal can be intelligible, what I have I speak can be easily heard and understood completely by another person, if I send the frequencies only up to 4000 hertz. So, even if the maximum frequency content is 4000 hertz, the other person can understand what I am trying to say. Now only thing is the texture of my voice will be different will not be the natural because it will lose high frequency components, but never the less the other person will be able to understand what I am trying to say.

So, the electric signal which is produced by the mic can be restricted to the maximum frequency of 4000 hertz of course, if I want to send high fidelity music, then I will have to allow all the frequencies up to 20 kilohertz. Now let us modulate a carrier wave using this speech or voice signal.

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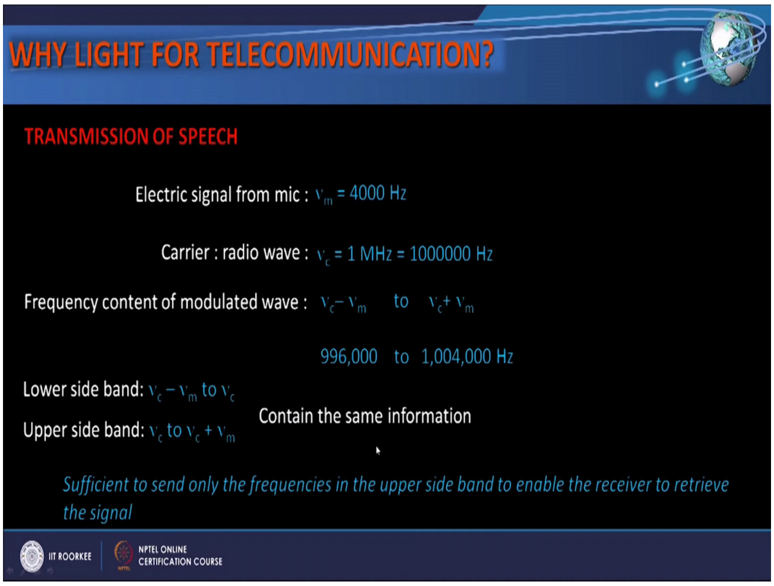

And let us choose radio wave as the carrier wave, then the electric signal from the mic has maximum frequency 4000 hertz, carrier which is the radio wave has a typical frequency one megahertz, then the frequency content of the modulated wave would be from nu c minus nu m to nu c plus nu m, which means 996000 to 1 million 4000 hertz. This range of frequencies I can divide into two parts two bands, one is from nu c minus nu m to nu c which is known as lower side band, and another is nu c to nu c plus nu m which is known as upper side band the thing is that both the side bands contain the same information. So, it is sufficient to send only one band of frequencies, let us say upper side band.

So, we can reserve a band of frequencies from one million to 1,00,4000 hertz for one voice communication.

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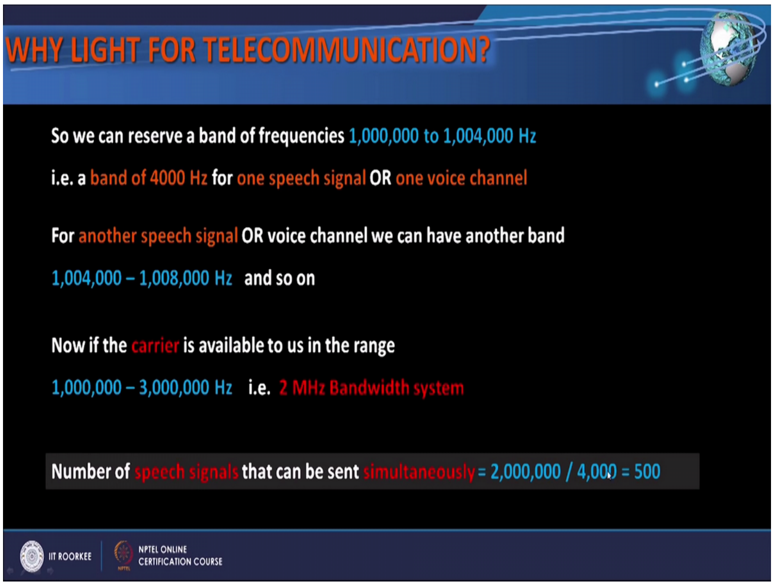

That is a band of 4000 hertz for one speech signal or one voice communication. For another speech signal I can use another band starting from 1,004,000 to 1,008,000 and so on. Now if the carrier that is available to me has a range of frequencies from one megahertz to three megahertz, that is I have a two megahertz band width system this is also known as a spectrum, the same is spectrum which is given to service providers, then in this two megahertz bandwidth system the number of speech signals that can be sent simultaneously would be two megahertz divided by 4000 hertz, that is 500. Because each voice communication will occupy a band of 4000 hertz, and the bandwidth available to me is 200 megahertz. So, I can carry out 500 voice communication simultaneously through this communication system.

Now, if instead of using radio waves or frequencies ranging from 1 megahertz to 3megahertz, if I choose to have a carrier frequency in the range of gigahertz let us 10 to the power 9 hertz, and let us say that the spectrum available to me is 1 gigahertz to 3 gigahertz. So, I have 2 gigahertz band width then the number of speech signals that can be sent simultaneously would now, be 500000.

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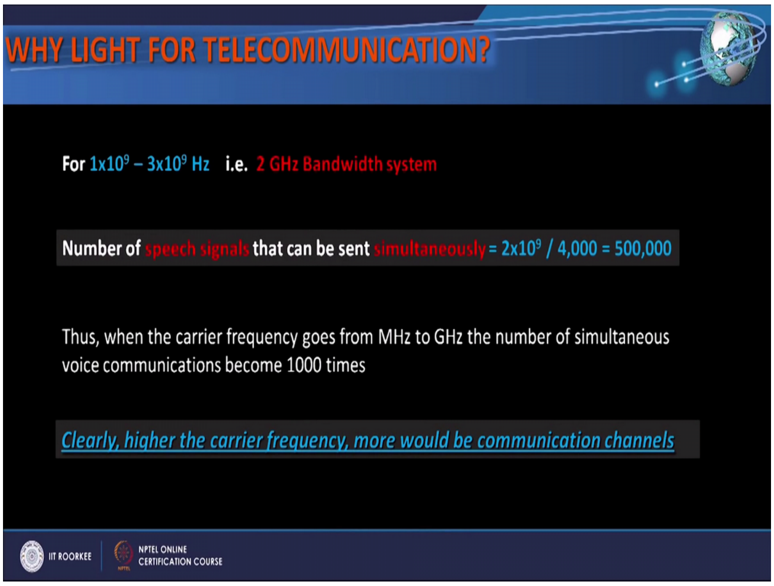

So, thus when the carrier frequency goes from megahertz to gigahertz, then the number of simultaneous voice communications become 1000 times. Clearly higher the carrier frequency more would be communication channels. This laws using analogue modulation, but these days nobody uses analogue modulation digital is the way to go.

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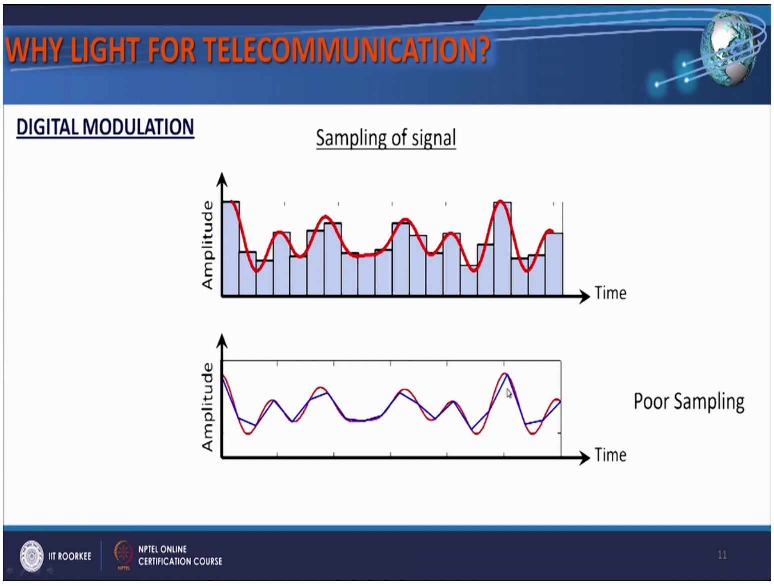

So, if I use digital modulation instead of analogue modulation, then what I need to do is I will have to sample the signal at regular intervals. I cannot send my signal directly as it is, instead I will sample discrete points at regular interval. The question is at what interval I should sample the points, at what interval I should pick up the amplitude of my voice signal. If I do it like this I sample it in such a way and then re produce the signal which is represented by the blue curve here, red curve shows the original signal, I can see my sampled points cannot gen regenerate the original signal. So, this is clearly upward sampling.

Let me increase the frequency of sampling or make the sampling interval is smaller, and then again if I look at it then this is now better, but there is there is even a scope of improving it.

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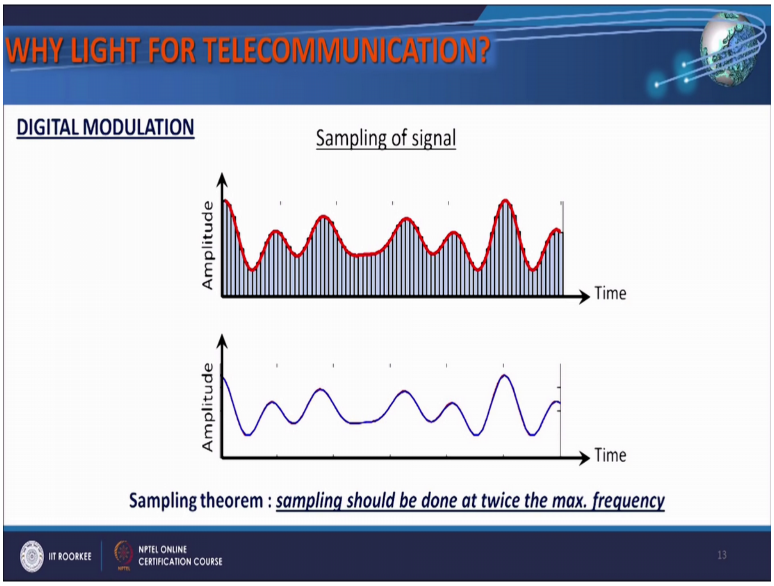

Let us increase the sampling rate and then see the regenerated signal now this is fine. So, where do we stop at what rate I should samples well the sampling theorem says, the sampling should be done at twice the maximum frequency. So, if my voice signal has maximum frequency new m, then I should sample the voice signal at frequency two new m. So, here it is digital modulation and communication of voice signal. So, this is the amplitude of the voice signal.

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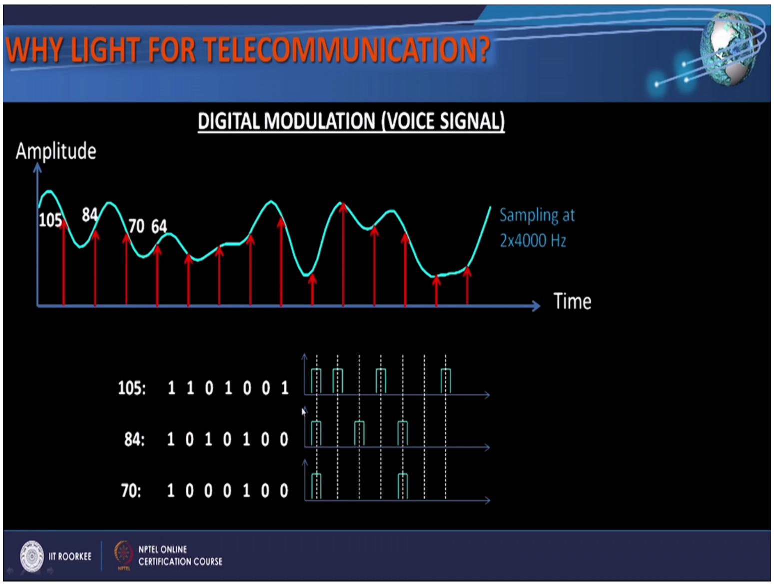

And I sample it at 8000 hertz, because I know that the maximum frequency content of a voice signal can be restricted to nu m. So, I sample it at 8000 hertz, what does it mean that in my one second length of voice clipping I sample 8000 points. I pickup 8000 points and record their amplitudes and let they are these amplitudes be like this. As soon as I do this I represent these amplitudes 105 84 70 64 and so, on.

So, 8000 such amplitudes in one second length, one second duration of my voice clipping then basically have digitized it, this is digitization, but this digitization is in decimal number system, computer cannot work on decimal number system, we need to convert it into binary. So, I convert these into binary 7 bit binary all these amplitudes, and then what I can do I can simply represent them with high and low pulses electric pulses. So, here for example, 1 1 0 1 0 0 1 would we represented by high high low high low low high pulses, and in this way I have a train of pulses a train of electric pulses a sequence of zeros and ones and this will go through communication system.

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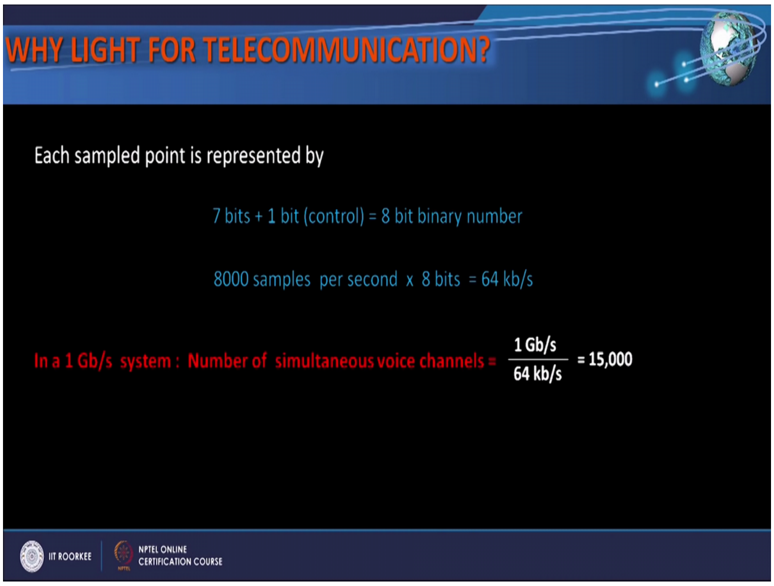

So, each sampled point is represented by 7 bit binary, and we reserve one extra bit for control. So, I required total of 8 bit binary number to represent each sampled point.

Now since I have sampled 8000 points over 1 second, and each sampled point is represented by 8 bit binary. So, I require 64 kilobits in 1 second. So, I require the data to be sent at the rate of 64 kilobits per second. Now if I have a 1 Gbps system a system which can transmit data at the rate of 1 gigabits per second, then the number of simultaneous voice communications that can be carried out would be 1 Gbps divided by 64 kbps which is equal to 15000. So, I can carry out about 15000 voice communications simultaneously.

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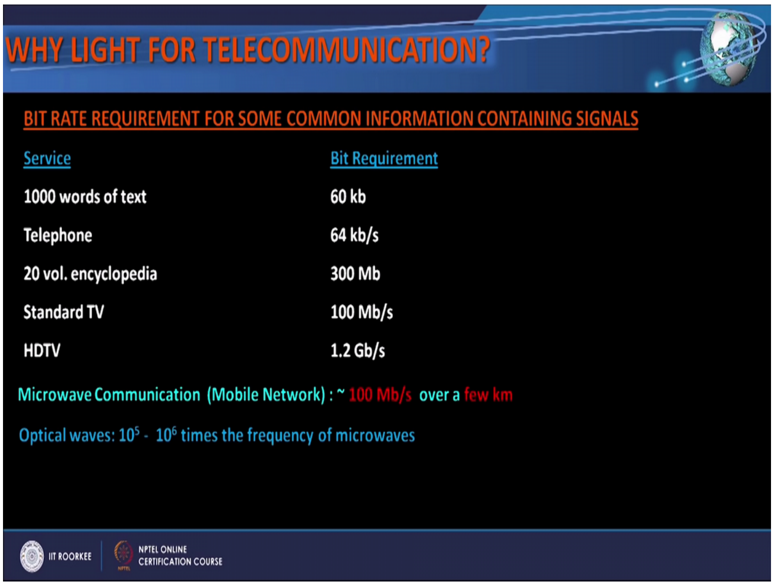

What are the bit rate requirements for different kind of services? If I am sending an email or a message then I am using text 100 words of text require about 60 kilobits for voice communication or telephonic conversation, I need to send data at 64 kilobits per second. 20 volumes I have encyclopedia I would require 300 megabits, is standard television is standard video will require sending data at the rate 100 megabits per second, and high definition television will require a data rate of 1.2 gigabits per second. So, these are the bit rate requirement for some common information containing signals.

Now, if I am using microwave communication that is mobile network, then a mobile network has a typical data rate of 100 megabits per second over a few kilometers, and you look a standard T V itself requires 100 megabits per second. So, mobile network would not be very efficient if I am sending a video signal over long distance. Instead if I use optical waves then optical waves have frequencies which are 10 to the power 5 to10 to the power 6 times, the frequency of the microwaves and this would lead to tremendous increase in the information transmission capacity.

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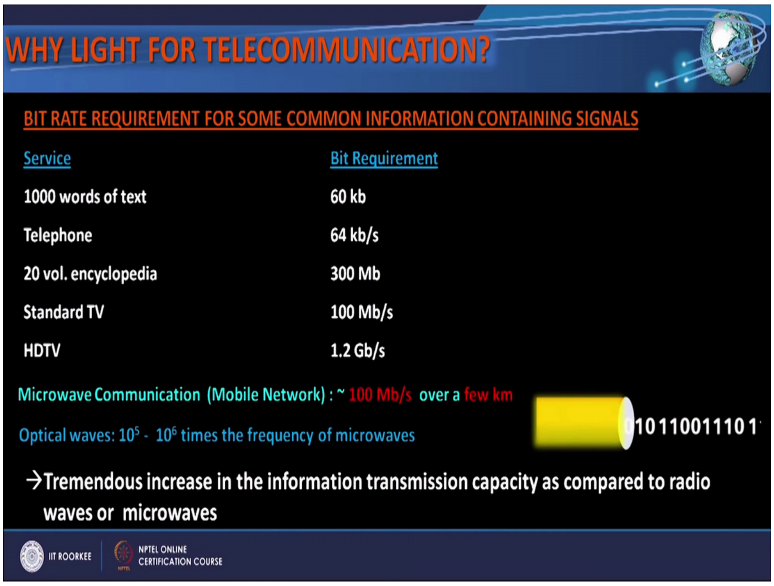

So, what you can do is basically you can use light waves and your high pulse and low pulse will represent these ones and zeros, and you send these light pulses through for example, optical fiber and carry out this communication, then we will be able to address the bitrate requirement for these kind of advance services also.

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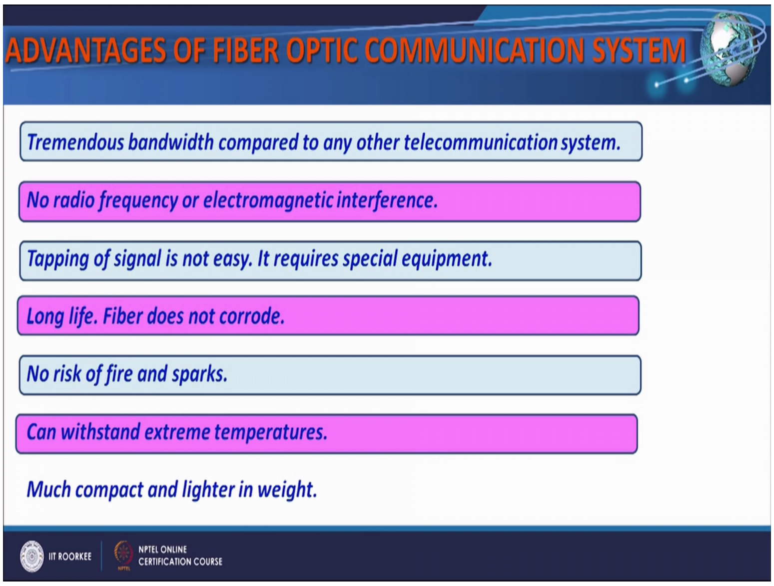

What are the advantages of fiber optic communication system over conventional communication systems? Well one is obvious that the bandwidth is tremendous as compared to any other telecommunication system. Second since these light waves are immune to radio frequency interference or electromagnetic interference, our signal is not affected by these kinds of noises. Third tapping of signal is not easy it requires special equipments, it is not just like in copper wire communication you just twist your wire to the line and then tap the signal, it is not that easy in case of optical fiber communication next is the fiber is made of glass and it does not corrode. So, the life of the fiber is very long fiber is made of glass again and it is dielectric. So, there is no risk of fire and sparks and glass can with stand extreme temperatures. So, it can work in very extreme environments, the glass fibers are much compact and lighter in weight as compared to copper wires.

In the end I would like you to try this out if possible, which is a very simple system can be made anywhere and will give you a feeling of communication through optical fiber; this is analogue communication and over a short distance.

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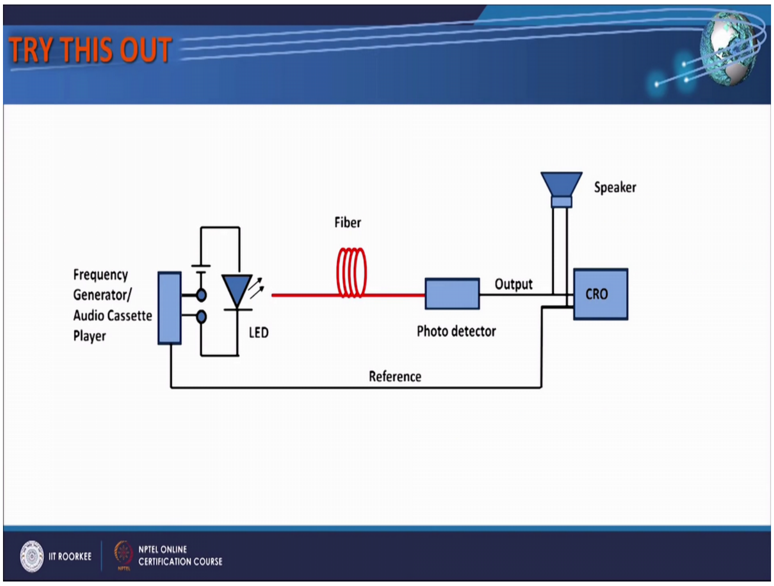

So, what you require here is a source of voice signal which can be a frequency generator or as simple as an audio player. You take any audio cassette player and take the signal out from the headphone jack and put it here. Take an led bios it and ride your signal which is coming out of your audio player on top of this, what it will do? As the voice signal will change the electric output will change, and it will change the intensity of led light.

So, in this way you can modulate the led light put this light through optical fiber this fiber can be a very simple plastic optical fiber very cheap plastic optical fiber, which is like this this kind of fiber you can use and then at the output end of the fiber you put a photo detector, convert this optical signal into electric signal, and feed it to a speaker if require you can put an amplifier in between. At the same time you can feed this signal output signal and the input signal apart of input signal to C R O for comparison free a typical set up looks like this.

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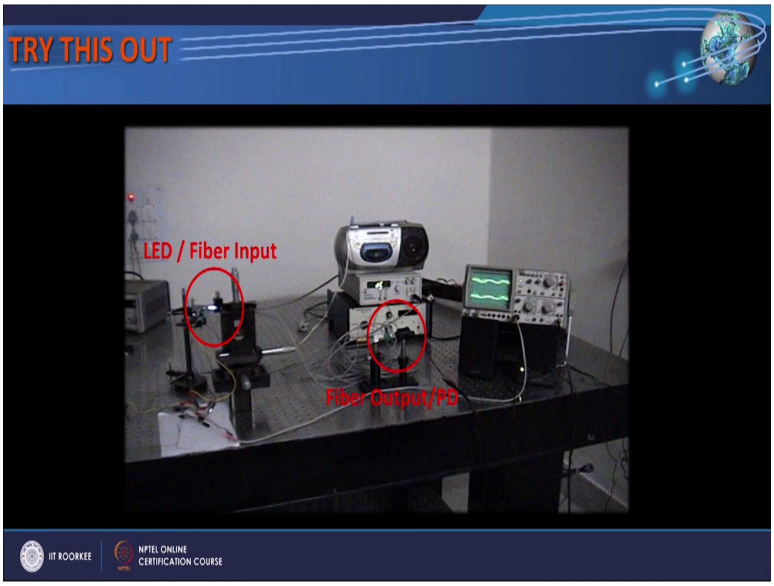

So, this is the signal generator audio player, which is used to modulate the light of an led and this light is fed into an optical fiber this grey colored optical fiber here, the output end of the fiber is here which is fed into a detector. The output of the detector is connected to the speakers and to the C R O this is the zoomed version. So, this is the optical fiber this is the led whose light has been modulated and this is the output end of the fiber and this is the detector and as the music goes on you can see the reference signal and the output signal on the C R O as well as listen it to through the speakers. So, try this out and it will give you a feeling of optical fiber communication, all though you cannot carry out this kind of communication over very long distances, because this fiber is very lousy and you are using a light source which is led, but never the less it would be a fun to do.

Thank you.