Data Communication

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Lecture No # 10

Transmission of Analog Signal-II

Hello and welcome to today's lecture on analog transmission. This is the second lecture on this topic. And in this lecture we shall cover these following points. I shall give a brief introduction on what we have discussed in the last lecture on the same topic.

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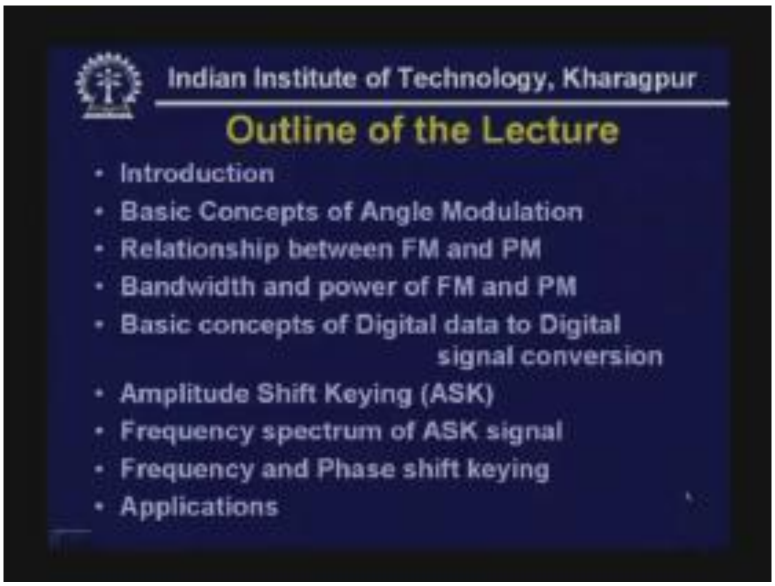

After that I shall introduce to you the basic concepts of angle modulation and essentially we will see angle modulation involves two types of modulation; frequency modulation and phase modulation. Then I shall discuss the relationship between frequency modulation and phase modulation. We shall then consider the bandwidth and power required for FM and PM transmission, then we shall switch to a different topic known as basic concepts of digital data to digital signal conversion where there will be three different types. first one will be Amplitude Shift Keying, we shall consider in detail the various issues related to Amplitude Shift Keying particularly frequency spectrum of ASK signal, the power requirement for transmission of ASK signal and also we shall discuss about the frequency and Phase Shift Keying. Then we shall end our lecture with applications of different types of digital signal conversion techniques. and on completion of this lecture the students will be able to explain the basic concepts of angle modulation, they will be able to distinguish between the FM and PM particularly their inter relationship, then explain the basic concepts of digital data to digital signal conversion, explain different aspects of ASK FSK PSK and QAM conversion techniques they will be able to explain bandwidth and power requirement for the transmission of ASK FSK PSK and QAM signals.

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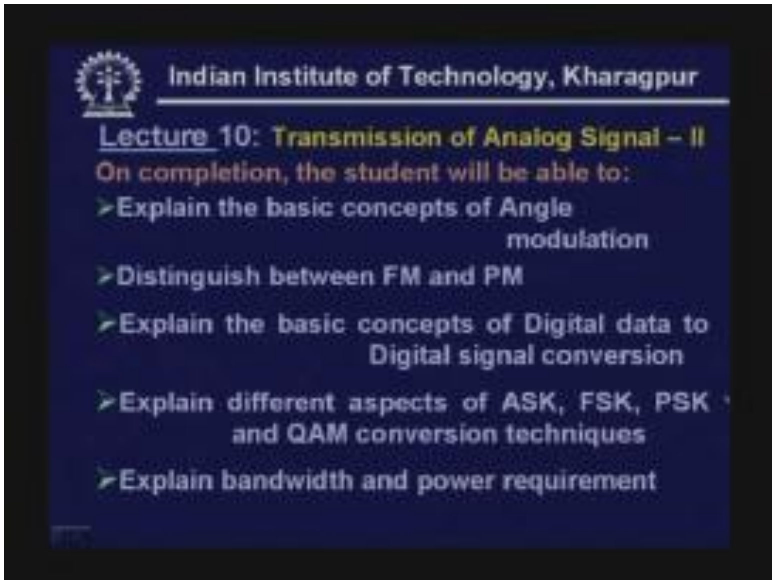

As I mentioned in the last lecture we have discussed about the amplitude modulation. We have started our discussion on analog modulation techniques and I have discussed in detail the amplitude modulation. And in this lecture I shall cover frequency modulation and phase modulation.

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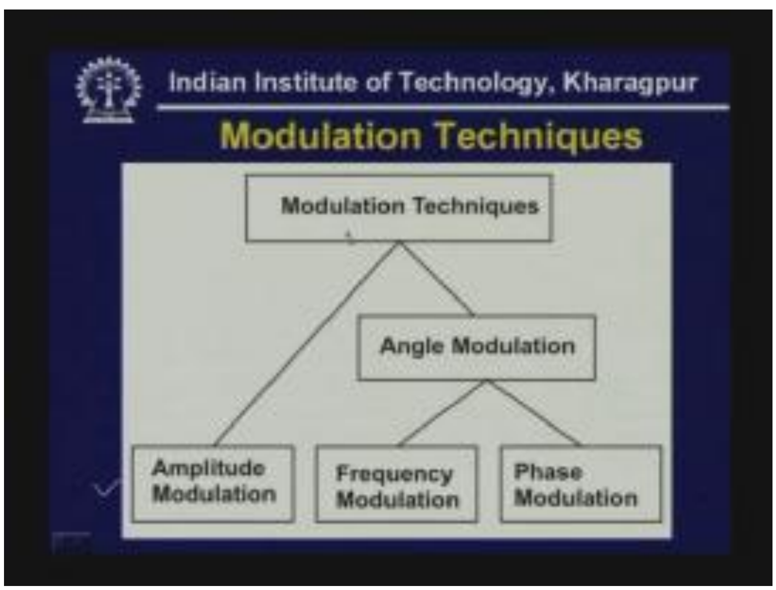

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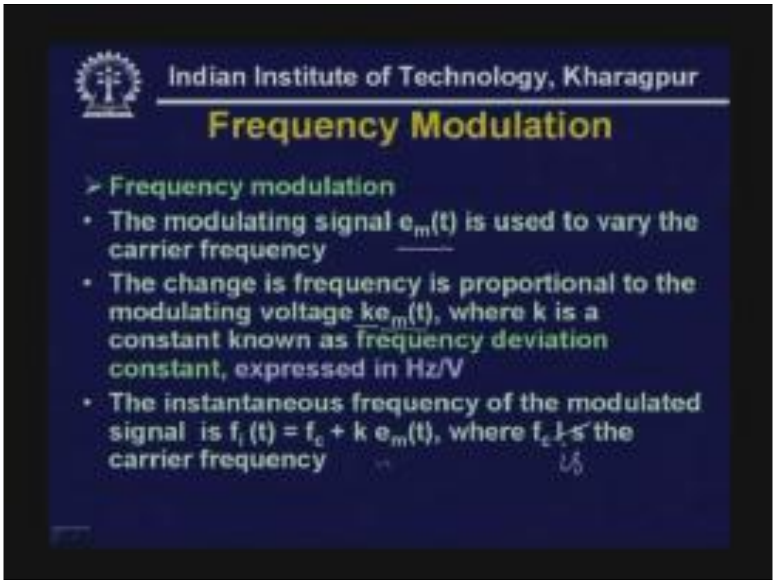

First let us start with frequency modulation. In frequency modulation the modulating signal $e_m(t)$ is used to vary the carrier frequency. And because of the name of frequency modulation the change in frequency is proportional to the modulating voltage. So here k is a constant and $e_m(t)$ is the modulating signal. This k is known as frequency deviation constant and it is expressed in Hz by V. It may be KHz per volt depending on the size of frequency deviation. And the instantaneous frequency of the modulated signal $f_i(t)$ is equal to f_c plus k into e_m (t) where f_c is the carrier frequency. Here this is in lower case and it is carrier frequency. So what we find is that around the carrier frequency the frequency will vary which will be proportional to the modulating signal. This is the basic idea behind frequency modulation.

Let us take a sinusoidal Frequency Modulated signal in which case the modulating signal $e_m(t)$ is a sinusoidal signal. As you can see E_m Cos 2pi f_mt. That means here the peak value is E_m and this is the Cos pi Cos 2pi f_mt so this is the sinusoidal signal (Refer Slide Time: 5:30). And as I have mentioned the frequency deviation $f_i(t)$ is f_c plus k $e_m(t)$ or I can substitute this to get the value of $e_m(t)$ to get f_c plus k e_m Cos 2pi f_mt or I can express it in this form f_c plus delta f Cos 2pi f_mt. And you can see delta f is the frequency deviation with respect to the carrier frequency. therefore we can represent the modulated signal that means the modulated signal s(t) becomes now E_c Cos pi t actually here you will have other terms as shown here (Refer Slide Time: 6:33) E_c Cos 2pi f_ct omega ct phi t.

Now this can be represented by E_c Cos 2pi f_ct plus 2pi f 2pi delta f_0 to t Cos 2pi f_mt dt.

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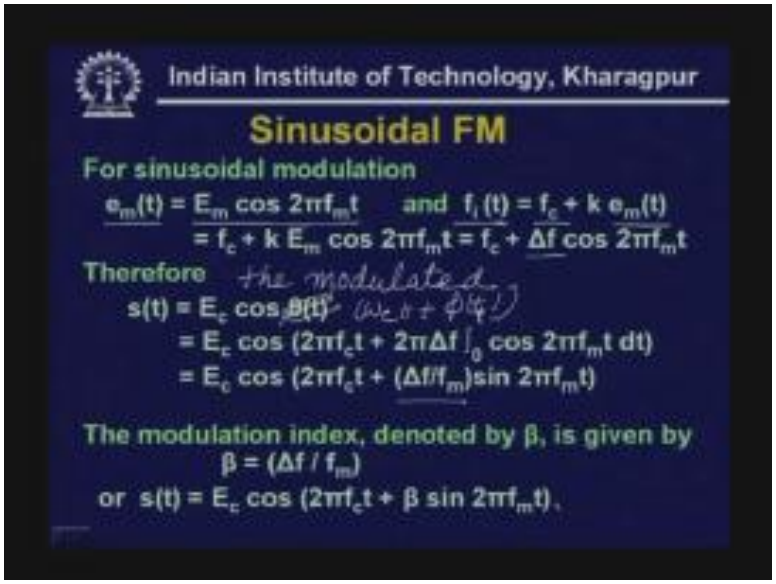

Now we can express it in this way and then it can be represented at E_c Cos 2pi f_ct plus delta f by f sine if we integrate it we get sine 2pi f_mt. So here we see that the amplitude does not change but the frequency is changing and here the change in frequency is represented by the modulation index beta and it is given by beta is equal to delta f by f_m so it has got relationship with the modulating frequency fm and therefore the modulating signal can be represented by E_c Cos 2pi f_ct plus beta sine 2pi f_mt so this is the representation of the modulating signal whenever you do frequency modulation and as you can see beta is the modulation index.

Now you may be asking what is the bandwidth of this modulated signal. In the last lecture we have seen for amplitude modulation whenever we modulate it by using sinusoidal wave the bandwidth is equal to twice the bandwidth of the modulating signal however the amplitude varies.

Let us see what happens in this case?

Because of the presence of this term (Refer Slide Time: 8:39) we find that the modulated signal will contain various frequency components f_c plus f_m f_c plus $2f_m$ and many other frequencies so the bandwidth will be much higher and this expression for the bandwidth is not very simple. You have to expand it using complicated mathematical expression.

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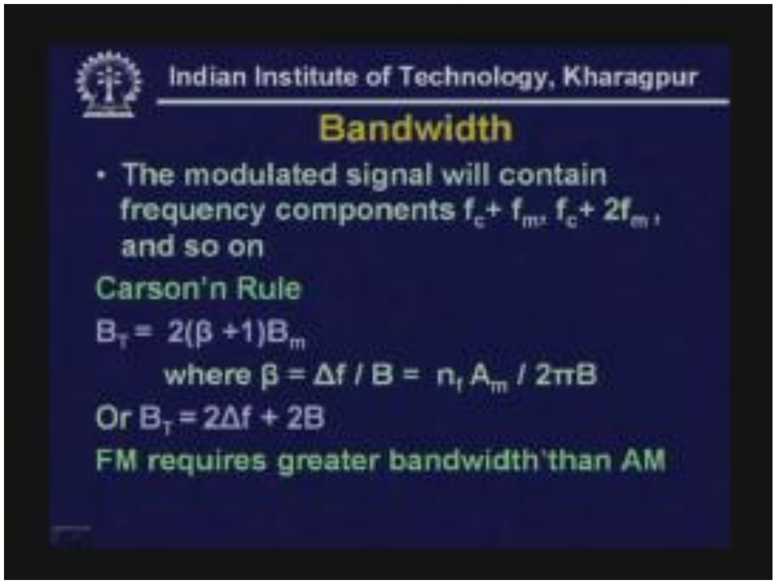

Instead of doing that we can represent the bandwidth by a simplified formula B_T is equal to 2(beta plus 1) B_m so Bt is equal to the bandwidth of the modulated signal B_T is equal to 2(beta plus 1) B_m where B_m is the bandwidth of the modulating signal. And as we have seen beta is equal to delta f by B which can be represented by nf Am by 2pi B or beta is equal to Bt bandwidth is equal to 2delta f 2B. So what we observe from the simple relationship is that the FM requires much higher bandwidth than Amplitude Modulated signal. So the bandwidth requirement for FM is much higher. Let us see from this relationship. And the peak deviation delta f is equal to 1 by 2pi nf into AM Hz where AM is the maximum value of mt and the value of that bandwidth also depends on the value of beta and for different values of beta the bandwidth will be different.

So what happens in this particular case?

Compared to AM signal in case of AM signal we have seen the bandwidth remains $2B_T$ or 2Bm B_T is equal to 2Bm but this is not true here.

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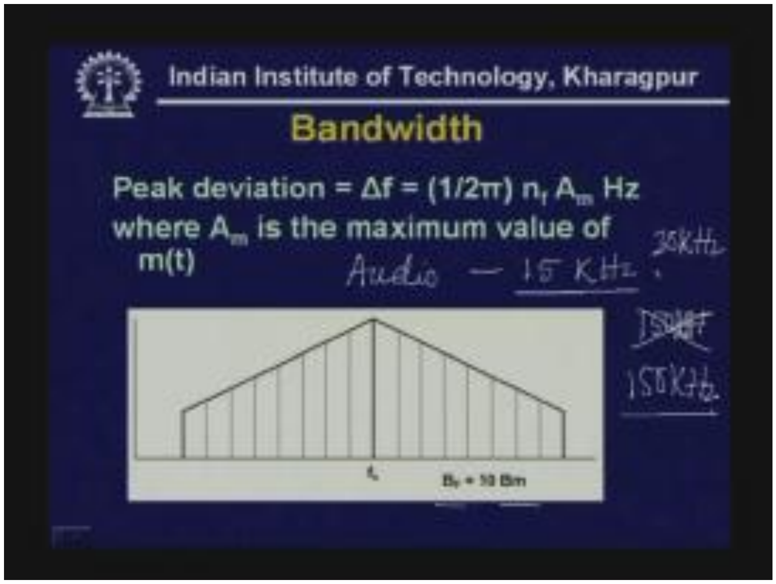

And another parameter was there. By increasing the modulation index we found that the signal gets distorted in case of AM. Does it happen in this case? The answer is no. In this case as the modulation index which is beta increases the effect of that on the modulated signal is the bandwidth increase but the distortion does not take place. That means higher value of beta will lead to higher bandwidth of the modulated signal. In case of FM now as we can see bandwidth requirement is ten B_m. The B_m is the bandwidth of the modulating signal and this bandwidth of the modulated signal is 10 B_m.

That means suppose we are trying to send audio signal using FM which has a bandwidth let's assume 15 KHz then the bandwidth of the modulated signal will be 150 KHz. In such a case we find for FM transmission the bandwidth requirement is much higher. Let us compare the two cases AM and FM. In case of AM for 15 KHz audio signal the bandwidth requirement will be 30 KHz. So with some gaps on either side you can utmost have another channel at the interval of 50 KHz or may be 40 KHz, the channels can be very closely placed. On the other hand in case of FM the stations has to be at least 200 KHz apart. That means because of higher bandwidth the number of channels that we can have in FM is limited because of higher bandwidth requirement of the FM signal.

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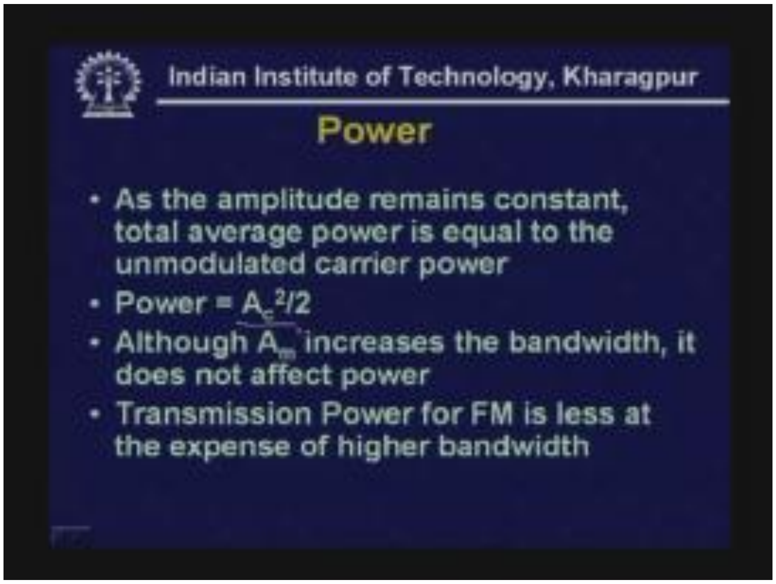

Let us look at the power. As the amplitude remains constant the total average power is equal to the unmodulated carrier power. Here as we can see the power requirement is A_c square by 2. That means although AM increases the amplitude of the modulated signal increases, increases the bandwidth it does not affect the power. And as a consequence the transmission power for FM signal is much lower. In case of AM we have seen that half of the energy is required for transmission of the carrier. And out of the first remaining half of the power one fourth goes out where half goes for upper side band and another half goes for lower side band. But here we see the power requirement is equal to the unmodulated carrier power. So here you require lesser power for transmission. However, this is possible at the expense of higher bandwidth. The conclusion is FM requires higher bandwidth but lesser power for transmission compared to AM.

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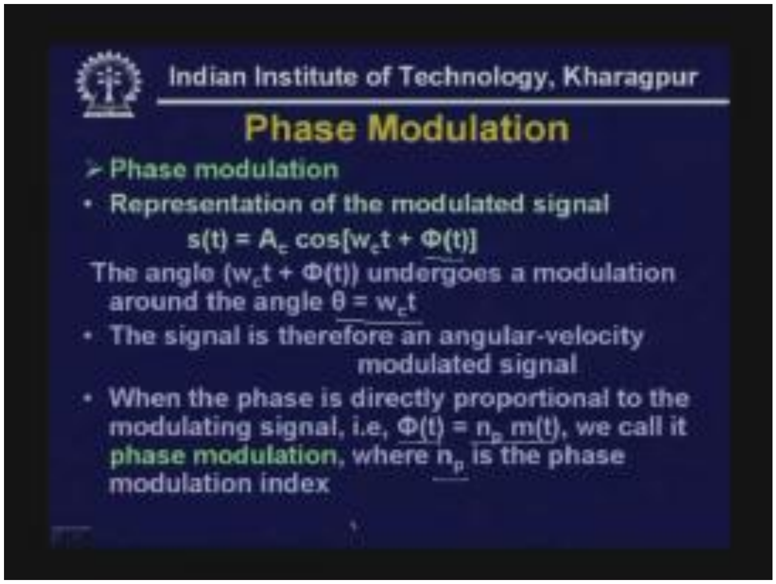

Let us now look at the phase modulation. In case of phase modulation we have seen that the modulated signal can be represented by s(t) is equal to A_c Cos W_ct plus phi(t) where this phase phi(t) is proportional to the phase of the signal.

The angle W_ct plus phi(t) undergoes a modulation around the angle phi is equal to W_ct that means around this phase there is change in the phase which is proportional to the modulated signal. So signal is therefore angular velocity modulated signal. When the phase is proportional to the modulating signal that means height is equal to n_p m(t) we call it phase modulation and here n_p is the phase modulation index just like n_f in case of frequency modulation.

One interesting observation is this FM and PM are very closely related. Let's see how they are related.

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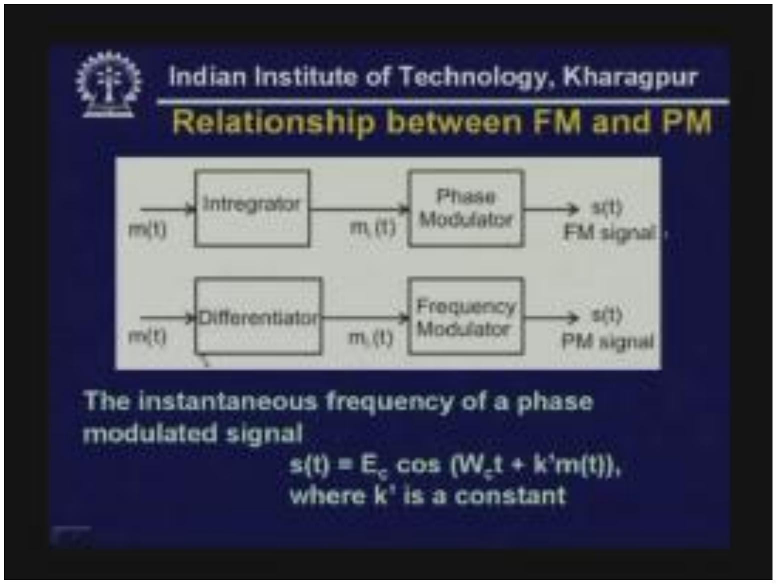

Here we find that if this is the modulating signal m(t) (Refer Slide Time: 15:40) and if this is integrated then passed through phase modulator we get Frequency Modulated signal. On the other hand if the modulating signal is passed to a differentiator then you do frequency modulation to get phase modulated signal. So you see we can get frequency modulate modulated signal by using a phase modulator however before that you have to do the integration of the modulating signal and the other one is also possible you can get phase modulated signal with the help of the frequency modulator. However, the modulating signal has to be differentiated. Let us see how exactly it happens.

Let the instantaneous frequency of a phase modulated signal is represented by s(t) is equal to E_c Cos W_ct plus k dash m(t) here k dash is a constant. Now let's assume that m(t) is derived as an integral of the modulated signal et. So e_m(t) is the modulating signal so that m(t) can be written as k double dash 0 to t et then with k is equal to k dash into k double dash we get s(t) is equal to Ec Cos W_ct kt 0 to t et so we can replace the m(t) here with this value (Refer Slide Time: 17:29) so this has been substituted in the previous expression and we get this expression.

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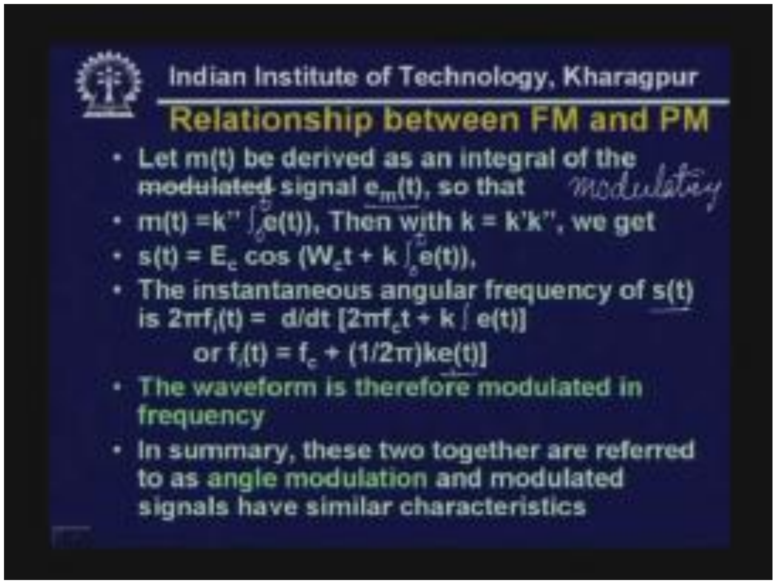

Now the instantaneous angular frequency of s(t) the modulated signal is 2pi $f_i(t)$. So if you differentiate it we get the frequency by differentiating the phase. So this is the phase we differentiate it and we get instantaneous frequency deviation is equal to f_c plus 1 by 2 pi k into et so we find that this waveform is therefore modulated in frequency because there is a presence of et which varies with frequency so this is $e_m(t)$ is the signal in time so we find that the frequency deviation is taking place. So whenever you do phase modulation frequency modulation also take place.

In summary these two together are referred to as angle modulation. in other words you will find this phase modulation, frequency modulation, angle modulation are used interchangeably because if you look at the waveform we will not be able to find any distinction.

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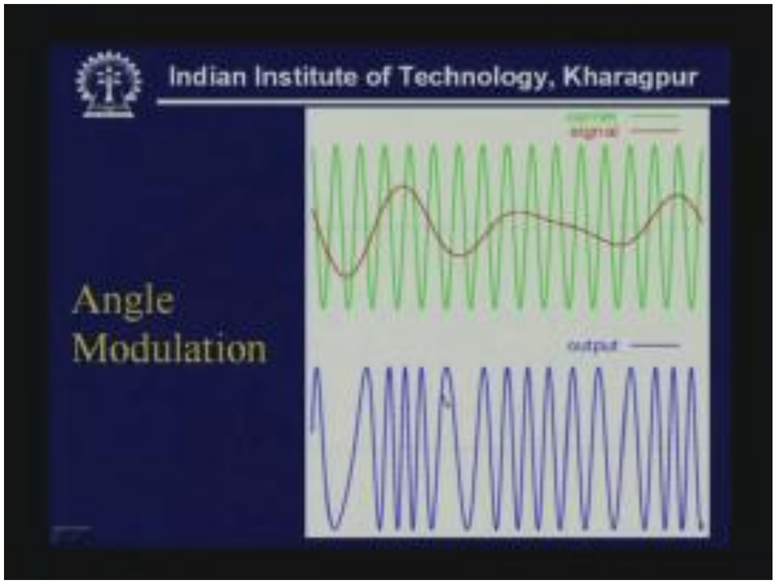

As you can see this waveform we have obtained by angle modulation. By looking at this you cannot tell whether it has been obtained by using frequency modulation or by using phase modulation. Let us see all the four cases together.

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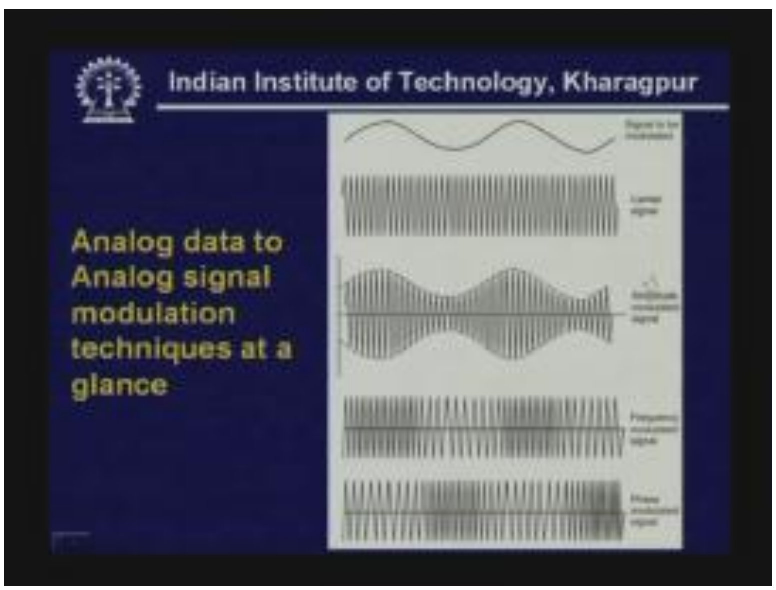

So here is the signal to be modulated or modulating signal, this is the carrier signal and here is the Amplitude Modulated signal (Refer Slide Time: 19:20) you see the amplitude is changing and then the envelope corresponds to the modulating signal and here we have got Frequency Modulated signal and here you have got phase modulated signal. We see that the nature of these two signals is absolutely same. Of course there are some differences in phase between these two signals that's why they will appear to be identical and their characteristics is same. So the characteristics of phase modulated signal and the Frequency Modulated signals are identical. That means the bandwidth requirement, power requirement for transmission is same for both Frequency Modulated and phase modulated signals. That's why together they are known as angle modulation, they are referred to as angle modulation.

With this we now change our gear and move from digital data to analog signal conversion.

There are many situations in which you have to convert digital data to analog signal because we have to transmit the signal through analog transmission media. Analog transmission media means it is bandpass in nature or there are many other advantages when we send data in analog form.

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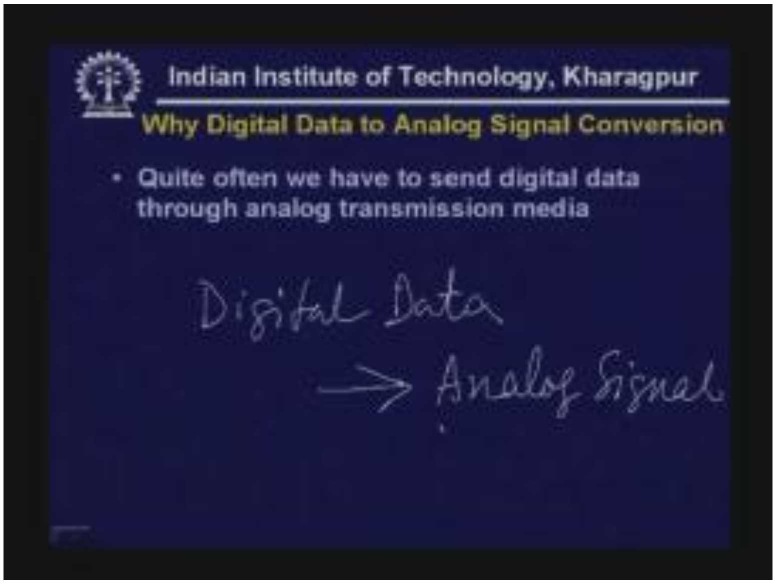

That means when the analog signal is transmitted it has got many advantages. We have already discussed about it. So the medium that is available can be analog in nature for example telephone line. If we want to use telephone line for transmission of data then we have to convert it into analog signal because the telephone line has been designed to send analog voice signal. So if you want to send data we have to convert it into analog signal. That is the basis for this digital data to analog signal conversion. Let us see how it happens.

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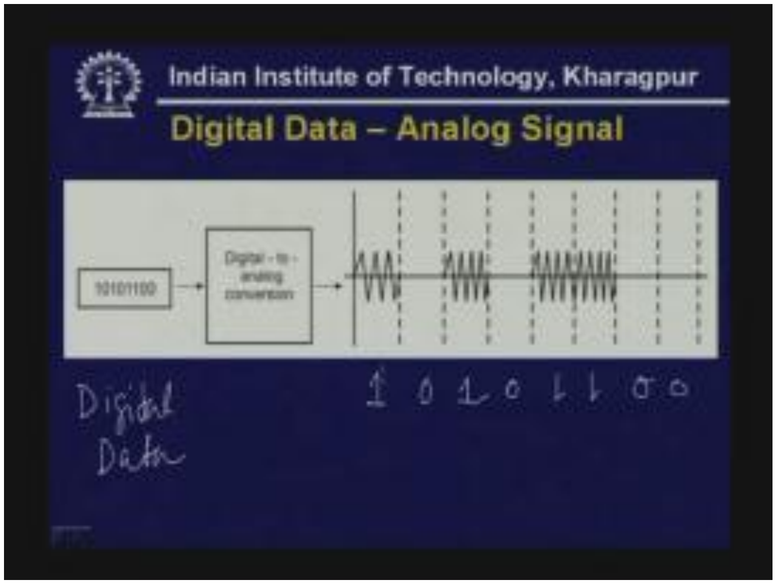

So here we see that you have got the digital data in terms of ones and 0s which is converted into some signal then we get the analog signal. So here according to this data modulation has been done to get analog signal. Here you see it is analog signal this corresponds to logic bit one, (Refer Slide Time: 22:10) this corresponds to 0, this corresponds to 1, this corresponds to 0, this corresponds to two ones, then two 0s so this corresponds to the data that we are transmitting. But instead of sending one we are sending analog signal. For 0 we are not sending anything and this is your analog signal.

There are three distinct types of digital to analog modulation technique. One is known as Amplitude Shift Keying, Frequency Shift Keying and Phase Shift Keying. And as we shall see Amplitude Shift Keying and Phase Shift Keying can be combined to have another type of modulation technique known as Quadrature Amplitude Modulation QAM. So we shall discuss all these four types of modulations ASK FSK PSK and QAM in this lecture.

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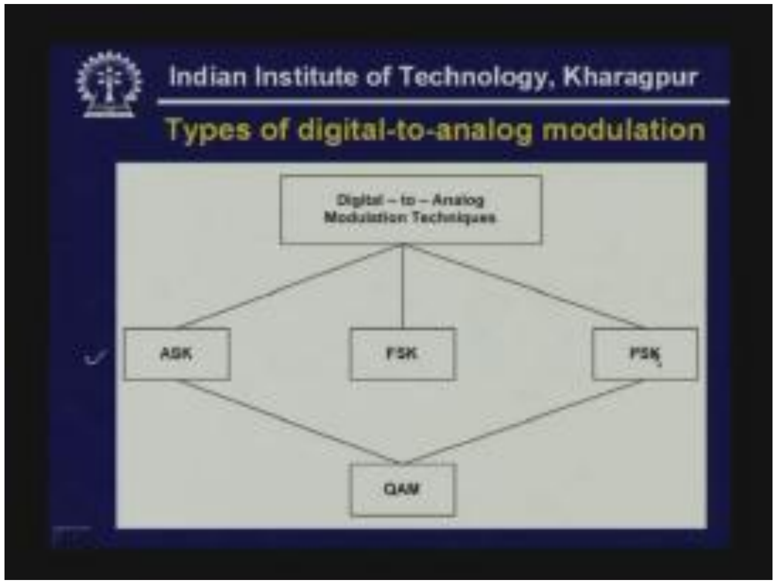

What is Amplitude Shift Keying?

Suppose the unmodulated carrier is represented by e_ct is equal to Ec Cos 2pi f_ct the modulated signal can be written as ke_m Cos 2pi f_ct. As we can see here the amplitude is being changed is proportional to the modulating signal. Now since the modulating signal can be either 0 or 1 what is possible is this amplitude in one case is A_1 and in the other case it is A_2 and as you can see here the carrier frequencies are same f_c. So without changing the frequency we are simply changing the amplitude of these two signals. For 1 we are sending one amplitude and for 0 we are sending another amplitude.

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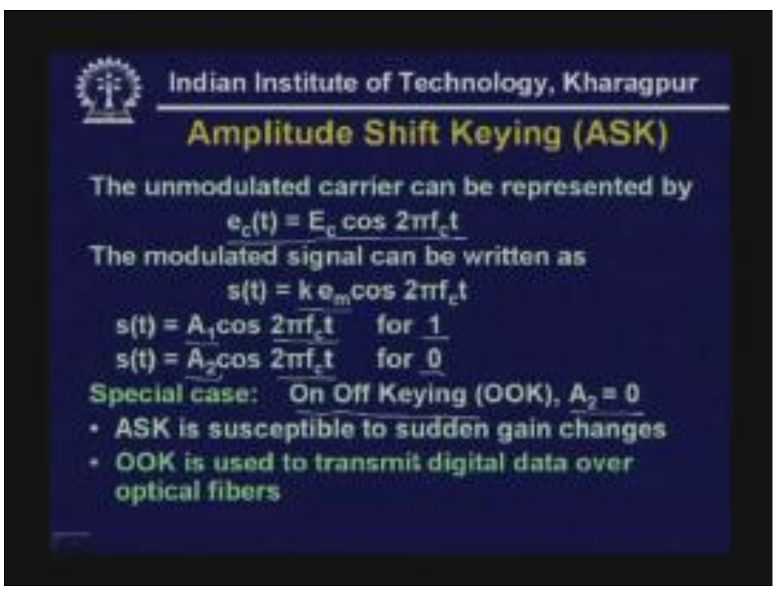

And a special case of this is whenever this At is equal to 0. That means whenever the data is 1 the amplitude of the modulated signal is A_1 and when the data is 0 the amplitude of the modulated signal is 0. This special case is known as On by Off Keying or OOK. And On by Off Keying as we shall see is susceptible to sudden gain changes. However, On by Off keying has been found to be very suitable for transmission of data through optical fiber. So in optical fiber we can say that we use On by Off Keying. That means whenever it is 1 we send some light coming from light emitting diode or laser diode and when it is 0 no light is transmitted through the optical fiber. This is how the modulation is done. So this is the OOK technique. On by Off Keying is used for transmission of digital data through optical fiber.

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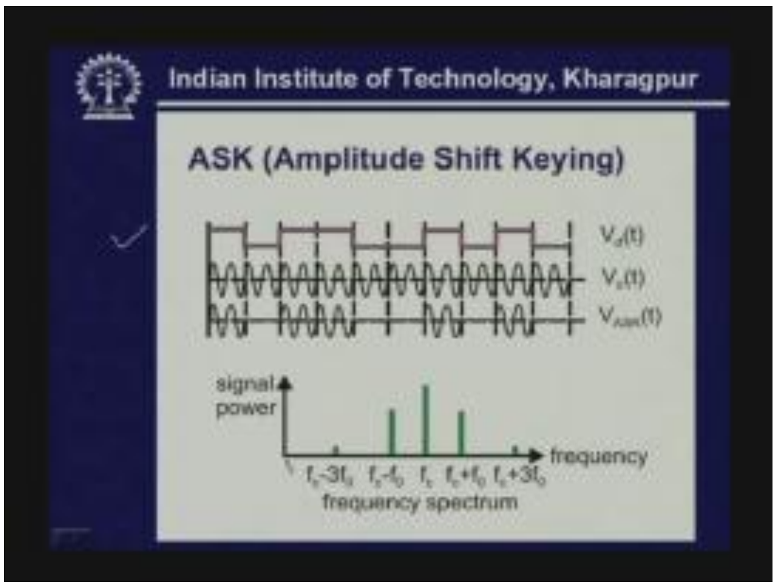

So this is how it happens as shown here. This is essentially On by Off Keying.

Now let us look at the frequency spectrum. If we look at the frequency spectrum you will find that bandwidth is relatively small compared to AM. In fact the bandwidth is decided by the bandwidth of the modulating signal. As we know if it is a square wave sort of thing then we have the fundamental the third harmonic and so on. so apart from the carrier frequency we have f_c plus f_0 the carrier plus the fundamental frequency of the signal then third harmonic fc plus $3f_0$ on the other side we have f_c minus f_0 f_c minus $3f_0$ and so on. Of course in the other spectral components we will have lesser and lesser amplitude.

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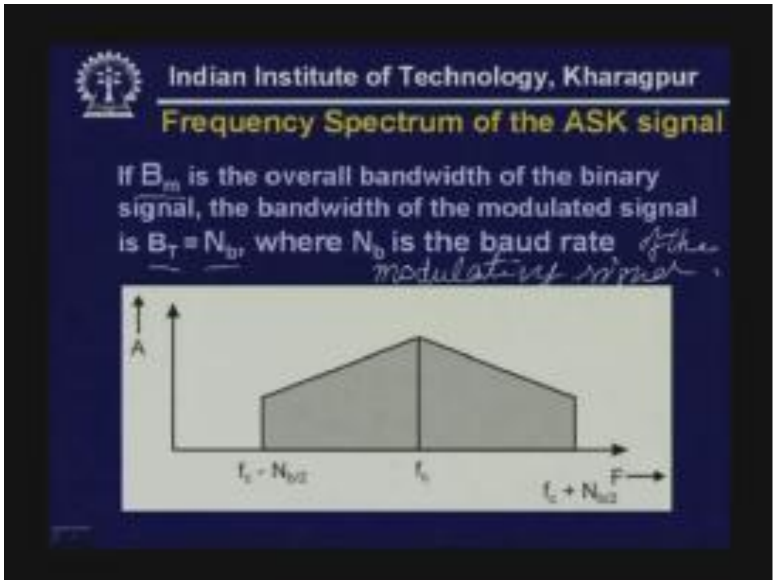

So if we look at the frequency spectrum of ASK signal you can see that if B_m is the overall bandwidth of the binary signal then the bandwidth of the modulated signal is B_t is equal to N_b so neither side we have f_c plus N_b by 2 and f_c minus N_b by 2 so bandwidth is equal to N_b square where N_b is the baud rate of the modulating signal. So we see that bandwidth is not really very high whenever we transmit using ASK. It is very similar to AM signal.

Now let us see Frequency Shift Keying.

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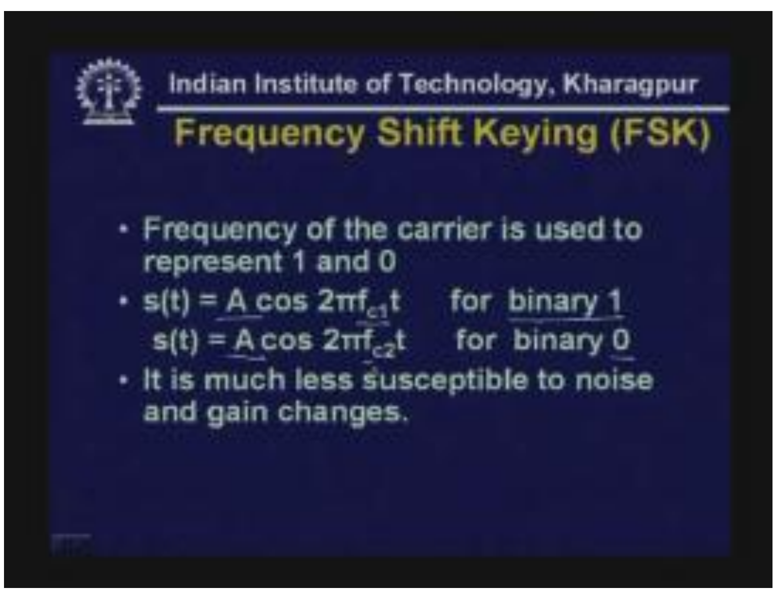

In Frequency Shift Keying the frequency of the carrier is used to represent 1 and 0. That means we are using two different frequencies, amplitude is kept constant. Whenever we are sending binary 1 we are using a carrier frequency f_{c1} and whenever we are sending binary 0 we are using a carrier frequency f_{c2}. And whenever we do that it has been found that it is much less susceptible to noise and gain changes. one drawback of Amplitude Shift Keying is that the amplitude is changing and as a consequence there is a possibility of high noise and that noise level is so high that it is not possible to identify or to detect the lower and higher level of the carrier signals or 0 level or little higher level of carrier signals. That's why the ASK signal is susceptible to noise and gain changes of the circuit or the amplifier. But in this case whenever we are using Frequency Shift Keying it is much less susceptible to noise and gain changes because we are sending two different frequencies and obviously because of noise the frequencies cannot change and the frequencies can be very easily detected at the other end.

Here is an example how exactly it happens.

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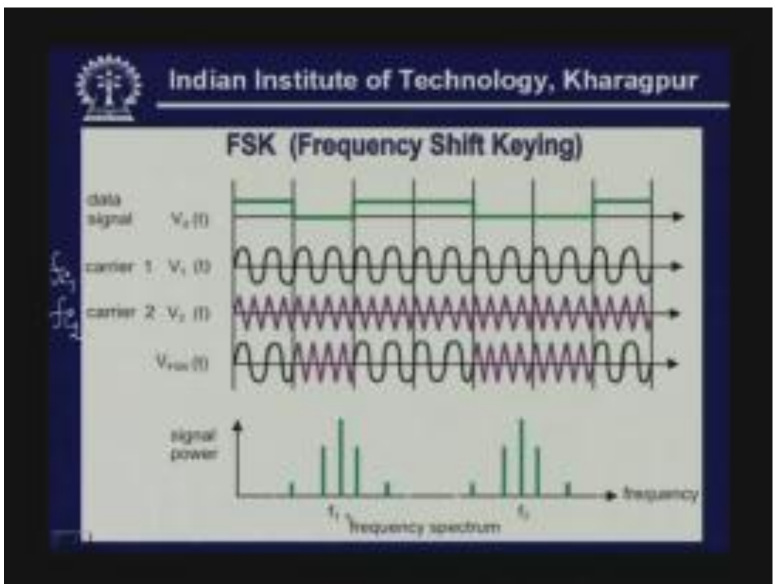

We find that here is your data 1011001 and this is one carrier with frequency f_{c1} (Refer Slide Time: 28:53) and this corresponds to carrier f_{c2}. So you see whenever it is 1 then we are sending carrier f_{c1} and whenever it is 0 we are sending the carrier f_{c2} and here we have got two ones so we are sending f_{c1} two 0s so two fc 0 twos and two f_{c1}. So here you can see that the frequency shift keyed signal looks like this. That means here is your Frequency Shift Keying signal what we receive at the receiving end so we have two different frequencies f_{c1} and f_{c2} are sent alternately depending on the data is 1 or 0.

Now the question is what is a frequency spectrum? As we can see this is equivalent to sending two ASK signals, one of carrier frequency f_{c1} and another of carrier frequency f_{c2}. As a consequence the bandwidth of the frequency shift keyed signal is much higher. So this corresponds to one ASK signal, this corresponds to another ASK signal as if we are sending one Amplitude Shift Keying having frequency f_{c1} or f_1 here as it is written or another one with carrier frequency f_2. So these two together will lead to much higher bandwidth for Frequency Shift Keying signal just like the case for FM signal compared to AM signal.

So here is the frequency spectrum of FSK signal. FSK may be considered as a combination of two ASK spectra centered around f_{c1} and f_{c2} as I mentioned.

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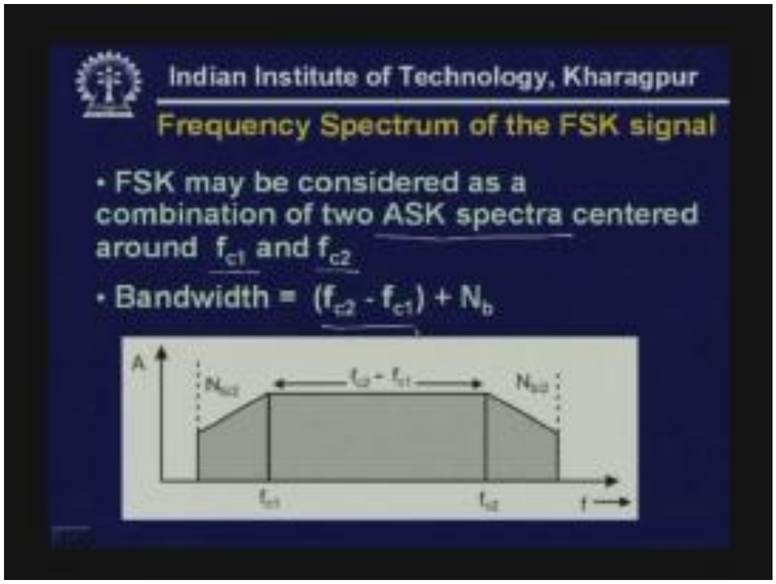

So the bandwidth is equal to f_{c2} minus f_{c1} so here f_{c2} minus f_{c1} (Refer Slide time: 31:00) then on either side you will have N_b by 2 so total bandwidth is f_{c2} minus f_{c1} plus N_b so bandwidth requirement is higher in case of FSK signal.

Now let us look at the third variation that is Phase Shift Keying.

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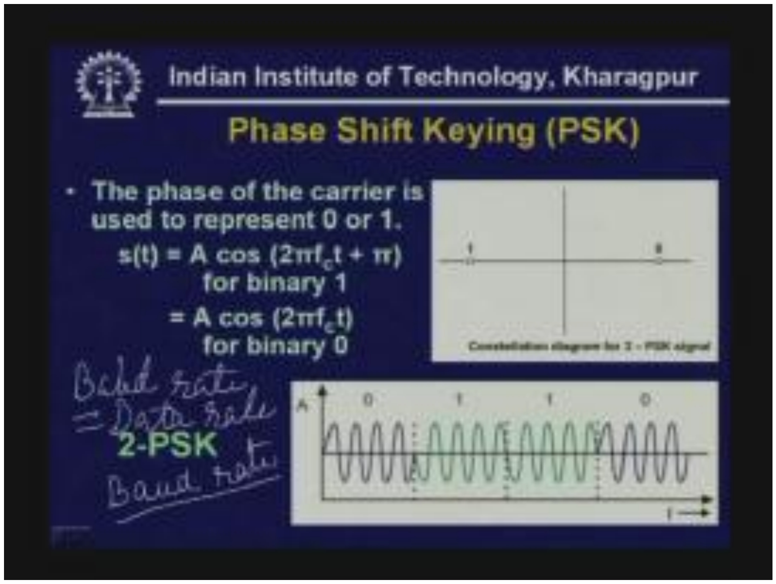

In Phase Shift Keying just like your phase modulation the phase of the signal will change or will be proportional to the modulating signal. That means whenever it is 1 we shall send in one phase and whenever it is 0 we shall send the carrier with another phase as it is shown here. So we are sending the carrier with phase shift of pi that means 180 degree for binary 1 and whenever it is 0 we are sending the carrier without any phase shift that means here the phase shift is 0. So the constellation diagram or phase state diagram as it is shown here if it is corresponding to 0 we find the phase shift is 0 and for 1 the phase shift is 180 degree. This is known as two PSK that means 2-Phase Shift Keying. We are using two different phases that's how you have got this name 2-PSK 2-Phase Shift Keying.

As it is shown here (Refer Slide Time: 32:36) this is the signal corresponding to 0 and this is the signal corresponding to 1. So here we see for 0 the phase is 0 we are starting with 0 and on the other hand for 1 the phase is 180 degree. This is also one so it is starting with phase of 180 degree and this is 0 so the phase is starting.

Therefore you can see that at the boundary whenever it is changing from 0 to 1 or 1 to 0 there is an abrupt phase shift which can be detected at the receiving end and to identify that this is corresponding to data of 0 and this corresponds to data of 1. This is how the Phase Shift Keying done and this is how a 2-PSK signal is generated and can be sent and this is the time domain representation.

Now we can extend the basic concept of 2-PSK modulation to have QPSK. In QPSK we shall be sending four different phases and since there are four different phases it is possible to represent one two bits for each signaling element. So whenever phase is 0 degree then it corresponds to bits 0 0. that means each signaling element is able to send two bits instead of one bit and if it is 90 degree then you are sending data bits 0 1. Whenever it is 180 degree we are sending data bits 1 0 and whenever the phase shift is

270 degree data bits are 1 1. So here is the phase state diagram; for 0 0 it is 0, for 0 1 it is 90 degree, for 1 0 180 degree, and for 1 1 it is 270 degree. So, the phase shift occurs in multiple of 90 degree in case of QAM.

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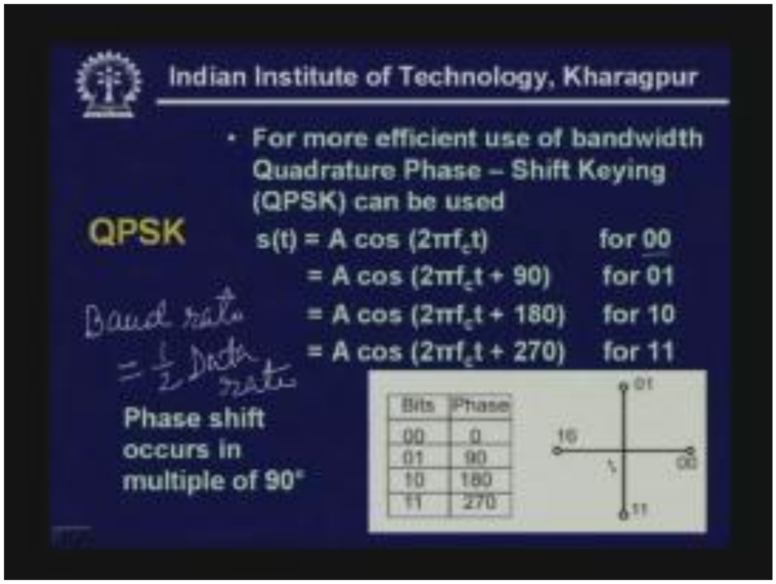

You may be asking what is the advantage that we have gained by this? Earlier what was happening was in this case you can see there is a term known as baud rate if you remember. Baud rate is essentially the rate of signaling element. So here you have got one signaling element, here you have got another signaling element and here you have got another signaling element. So in case of 2-PSK the baud rate and data rate is same because for one data we are having one signal element, for another data bit we are having another signal element that’s why baud rate and data rate is same.

But in this particular case that is not true. We find that each signaling element corresponding to phase 0 can have two bits so here the baud rate is half the data rate. Or in other words data rate is twice the baud rate. That means the number of signal elements will be half that of the data rate. That means for two bits we are getting one signal element and as a consequence you are able to send higher data rate having the same baud rate so that is the advantage of this QPSK.

The idea can be extended further. Here as you can see this is an 8-PSK signal and here the phase shift key is by 45 degree. So 0 0 0, 0 0 1, 0 1 0 as you can see, this 0 0 0 corresponds to the 0 degree, 0 0 1 corresponds to 45 degree and so on as it is shown in this table.

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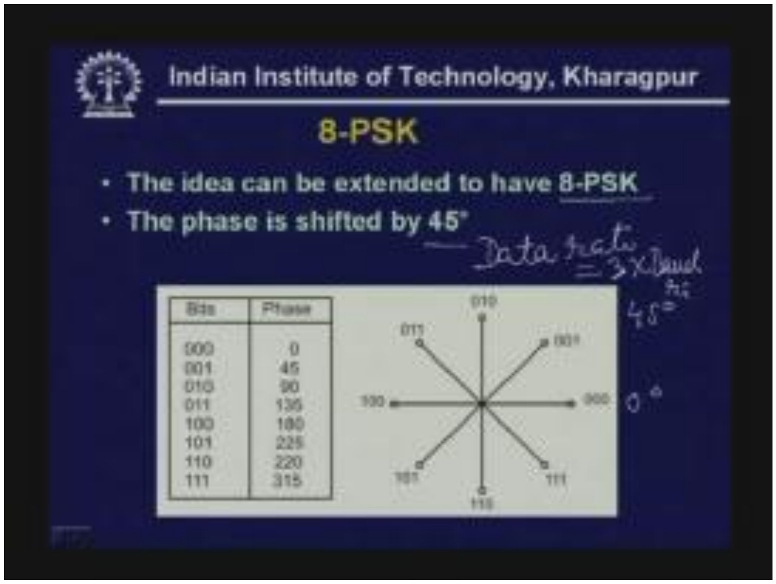

So 0 1 0 is 90 degree, 0 1 1 is 135 degree, 1 0 0 is 180 degree, 1 0 1 is 225 degree, 1 1 0 is 220 degree and 1 1 1 is 315 degree.

So in this case we are able to send three bits per signaling element. So in that case the data rate will be equal to three times the baud rate because we are able to send three data bits per that modulated signal element so as a consequence for the same baud rate we shall be able to send higher data rate.

However, there is some limitation at the receiving end and the limitations come because of the ability of the equipment to distinguish small differences of phase limits. Therefore as a consequence the potential bit rate is limited. That means the ability of the equipment to distinguish the small phase shift leads to a restriction on the maximum bit rate that can be transmitted over the medium. So what’s the way out? The other alternative is apart from changing the phase we can also change the amplitude. In other words we can combine change in amplitude and change in phase leading to what is known as QAM Quadrature Amplitude Modulation. So in this case it is a combined modulation technique so QAM can be considered as a combination of ASK Amplitude Shift Keying plus Phase Shift Keying.

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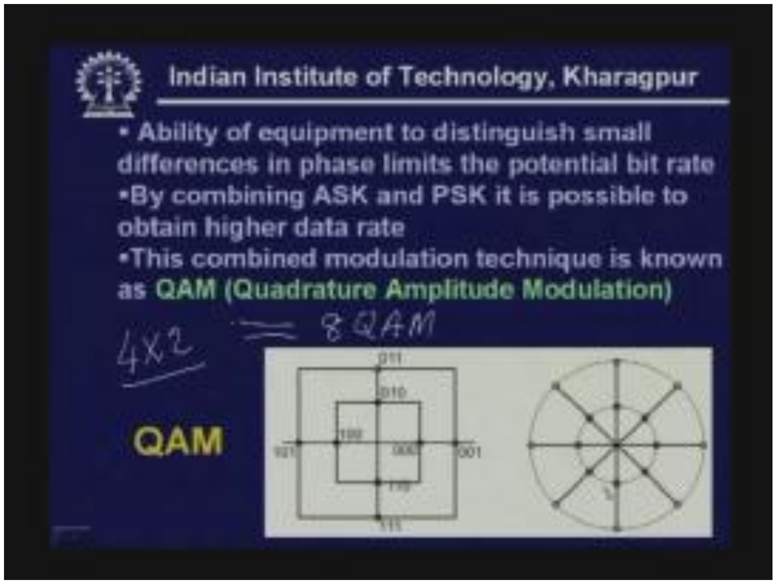

For example, this is your 8 QAM. So in this case as you can see we have used two amplitude levels. This is one amplitude level and this is another amplitude level and four phase values so 0, 90, 180 and 270 so four phase values and two amplitude value so as a consequence we are getting 4 into 2 and that leads to your 8QAM. And here you have got another constellation diagram or phase frequency diagram (Refer Slide Time: 39:51) where you see we have used again two amplitudes and 1 2 3 4 5 6 7 8 so 8 phases so here it is possible to have 2 into 8 is equal to 16QAM. So we find that for each signal element there is change in phase or frequency. That means you can have two different amplitudes and eight different phases leading to four different bits to be sent per signal element so we can send them at higher data rates so this is the 16 QAM. So in this way you can keep on extending the number of phase changes and number of amplitude changes.

However, you will find that number of amplitude changes is much lower than the number of phase changes. In other words detection of phase changes is easier than the detection of amplitude of levels because amplitude levels usually get corrupted because of noise. The phase changes usually do not get corrupted because of noise. That’s why normally the number of amplitude levels is less than the number of phase levels. So here you see the possible bit rates for different baud rates.

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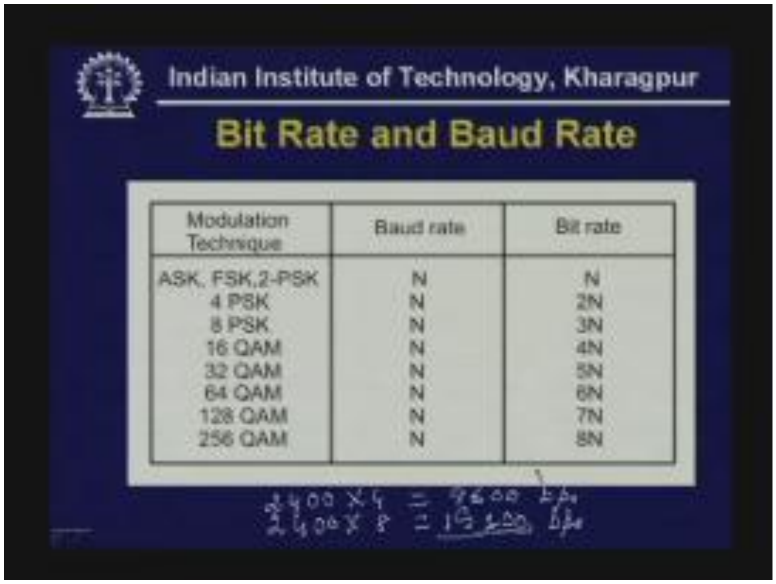

For ASK, FSK and 2-PSK we find baud rate and baud bit rate are same. For QPSK as I have explained if baud rate is N then the bit rate is 2N. For 8-PSK as I have explained for baud rate of N you get bit rate of 3N, for 16 QAM for baud rate of N you get bit rate of 4N. Similarly for 32 QAM for a baud rate of N you get 5N bit rate, for 128 QAM for baud rate of N you get bit rate of 7N and for 256 QAM for baud rate of N you get 8N.

In other words the data rate can be eight times that of baud rate and this has very good application in modem. Modem stands for modulator demodulator. It converts digital signal to analog signal using either ASK, FSK, PSK or QAM that means modulation is done at the transmitting end then at the receiving end by demodulation you get back the original data so that is what is done in modem.

Now let us consider the bandwidth of a typical telephone line.

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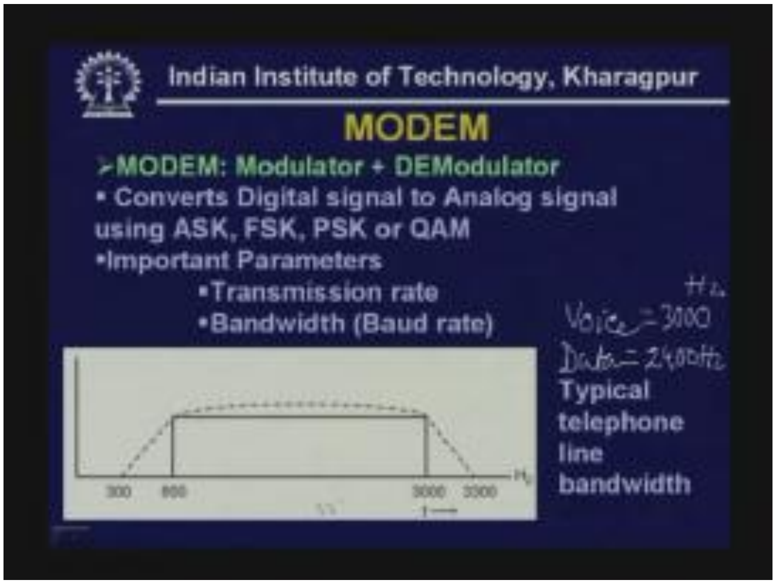

Here we find that for voice the bandwidth is 3300 minus 300 so 3000 Hz. But for data the bandwidth is restricted that means it is 3000 minus 600 so you get 2400. So this is the bandwidth that you get for transmission through telephone line. So whenever your bandwidth of the channel is only 2400 Hz then what is the data rate that is possible for transmission through telephone line.

Let us now go back to the previous table. So, if we use 16 QAM then the data rate can be 4N that means your bandwidth of the channel is 2400 into 4 that means we get 9600 Bps. Hence by using 16 QAM the data rate possible for transmission using modem is 9600 Bps. On the other hand if you go for 256 QAM the data rate possible is 2400 into 8 that means 19200 Bps. Thus it is possible to transmit at a much higher data rate than the bandwidth of the channel by using suitable modulation technique like QAM which is a combination of ASK and PSK. Hence we see that this modulation technique is finding very good use in modems which we normally use for connecting our computer from home to office or from home to the internet service provider so modems have many applications.

Therefore this AM digital to analog modulation technique has found extremely good application in modem. Now it is time to summarize what we have discussed in the last two lectures. We have discussed about transmission of analog signal where we use different modulation techniques such as amplitude modulation, frequency modulation and phase modulation.

We have seen that in case of amplitude modulation there is a maximum limit of the modulation index that means the value of N has to be 1. If the value of N is greater than 1 then the signal gets distorted. In other words at the other end it is not possible to recover the signal. However, the power required for transmission the amplitude modulation signal is higher that's why the Frequency Modulated signal and phase modulated signal which are combined and which are known as angle modulation requires lesser power however at the expense of higher bandwidth so FM gives you very high quality signal because it is not affected by noise. AM signals Amplitude Modulated Signals gets corrupted by noise and disturbances. From our common experience we find that whenever it is cloudy or it is raining when there is lightening there are lots of disturbances. On the other hand the FM signal does not get that much noise because frequency is not affected. However, the bandwidth requirement is much higher for frequency FM signals.

Coming to the digital data digital analog signal we have discussed ASK, FSK, PSK and also QAM and we have found that ASK is simple and particularly the On by Off Keying is very attractive which has found application in optical communication where that optical signal is modulated by using this OOK On by Off Keying and bandwidth requirement is less. On the other hand the FSK and PSK the bandwidth requirements are higher compared to ASK signal and we have seen how PSK and ASK can be combined to have higher baud rate for transmission of high speed data through the modem. We have also seen that using lower bandwidth channel we can send data at a higher speed. So with this we conclude our lecture. However, there are some review questions.

Review Questions:

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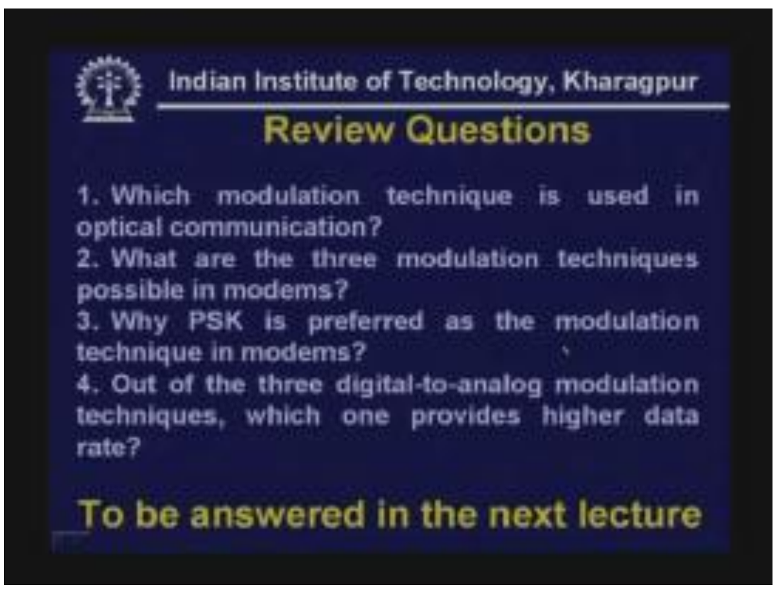

1) Which modulation technique is used in optical communication?
2) What are the three modulation techniques possible in modems?
3) Why PSK is preferred as the modulation technique in modems?
4) Out of the three digital-to-analog modulation techniques, which one provides higher data rate?

These questions will be answered in the next lecture. Now it is time to give the answer to the questions of lecture-9.

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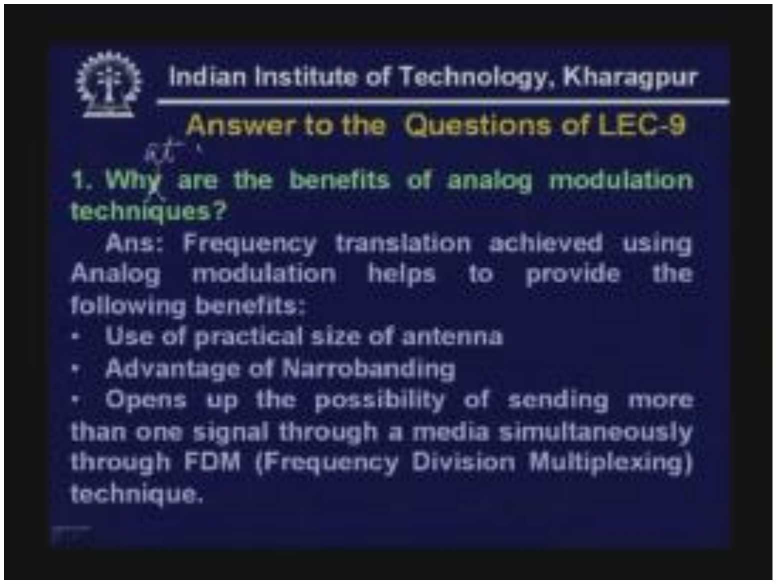

1) What are the benefits of analog modulation techniques?

Answer: Frequency translation achieved using analog modulation helps to provide the following benefits. As I have discussed in detail it allows you to have antenna of practical size, it helps you to use the advantages of narrowbanding then it opens up the possibility of sending more than one signal through a media simultaneously through Frequency Division Multiplexing FDM technique. Later on we shall discuss in detail the multiplexing technique where we shall see that the Frequency Division Multiplexing has some use.

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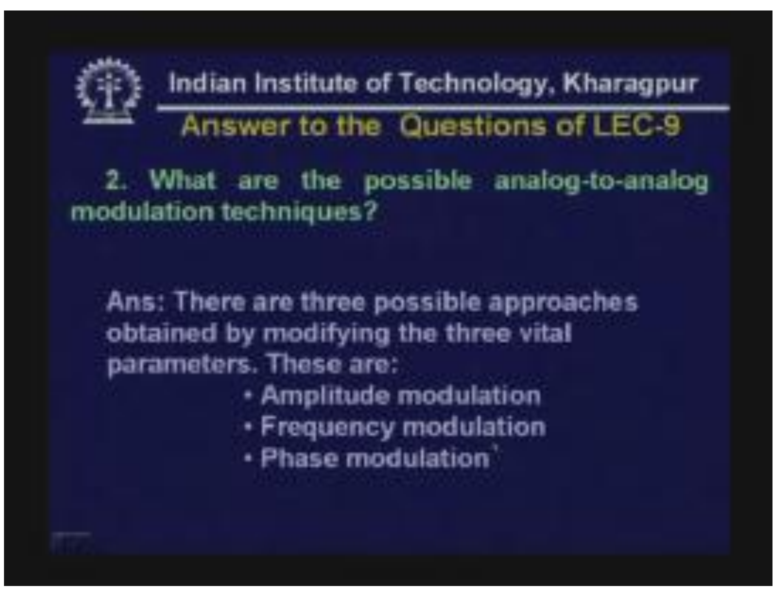

2) What are the possible analog-to-analog modulation techniques?

As I have already discussed there are three possible approaches particularly modifying the three vital parameters like amplitude, frequency and phase and the modulation techniques are known as amplitude modulation, frequency modulation and phase modulation. However, as you have seen that frequency and phase modulations are very similar in some ways and that's why they are known as angle modulation.

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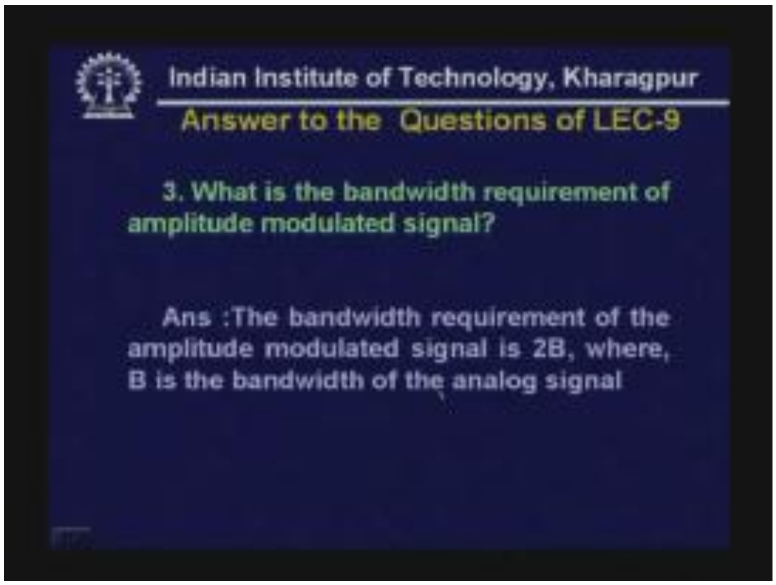

3) What is the bandwidth requirement of Amplitude Modulated signal?

Answer: The bandwidth requirement of the Amplitude Modulated signal is 2B where B is the bandwidth of the analog signals. So we find that the Amplitude Modulated signal or AM signal requires lesser bandwidth for transmission.

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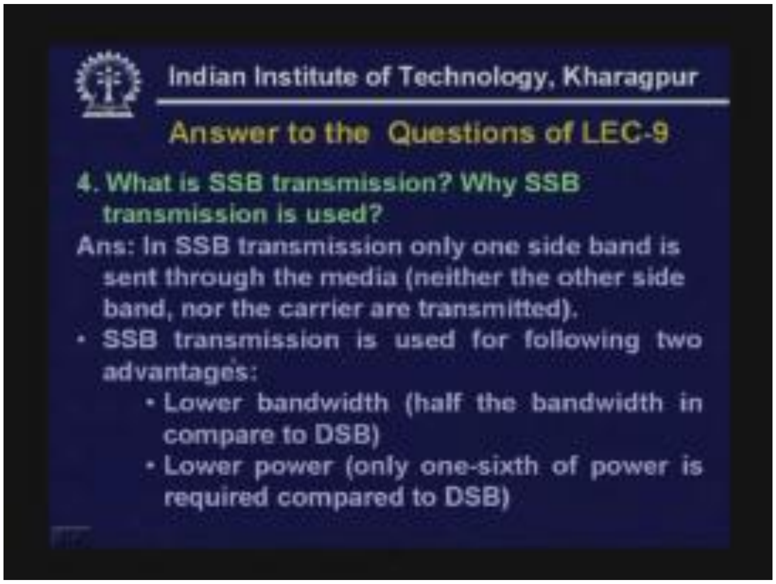

4) What is SSB transmission? Why SSB transmission is used?

Answer: In SSB Single Side Band transmission only one side band is sent through the media neither of the other side band, lower or upper side band is sent nor the carrier is transmitted so only one side band is sent so the carrier is not transmitted and one of the two side bands is transmitted.

SSB transmission is used for the following two advantages; lower bandwidth half the bandwidth of the double side band transmission and lower power and it requires about one six of the power that is required for Single Side Band transmission compared to Double Side Band transmission.

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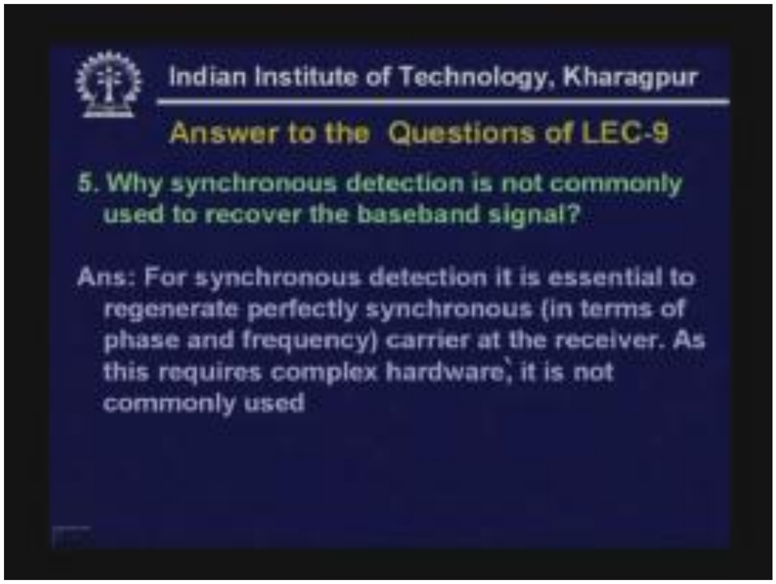

5? Why synchronous detection is not commonly used to recover the base baseband signal?

Answer: For synchronous detection it is essential to regenerate perfectly synchronous carrier at the receiving end and it has to be perfectly synchronous in terms of phase and frequency which is very difficult to do and as this requires complex hardware it is not commonly used. On the other hand we have already discussed very simple circuit by using diode and RC circuit elements. So that kind of detector is commonly used in AM receivers. So, that answers all the questions that were given in a last lecture and with these we come to the end of today's lecture, thank you.