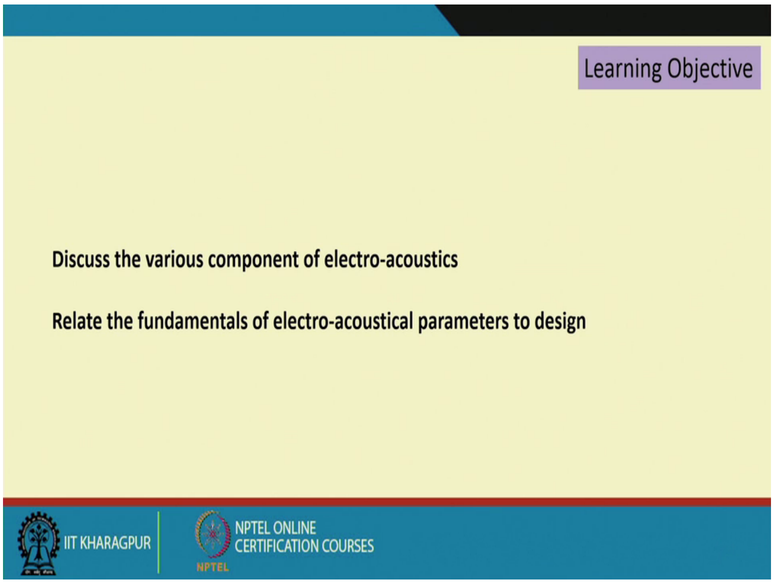
Architectural Acoustics
Prof. Shankha Pratim Bhattacharya
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture – 26
Electro – Acoustics – I

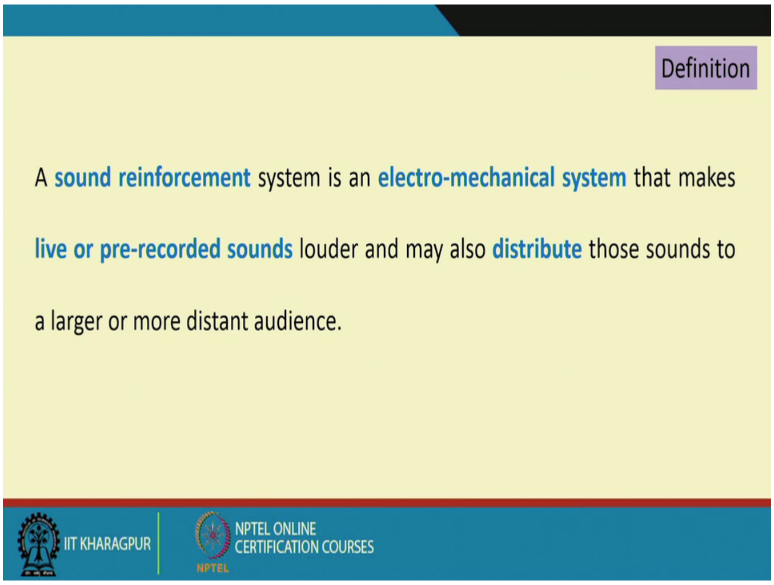
Good morning, student, welcome to the NPTEL course on Architectural Acoustics today we will going to start the sixth week program of the total 8 week module. So, lecture number 26, today will deal with the Electro- and I have two lectures for that, the lecture 27 is also on the Electric Acoustics.

(Refer Slide Time: 00:41)



So, let us first go to the learning objective of this 26th lecture. The electro-acoustic is a one of the integral part of the acoustics or modern days acoustics I must say and the electro acoustical component it has actually various components and from the various component there are various fundamentals and the some properties of the those component. In the lecture number 26 we will discuss the various component of the electro-acoustic that is first and then will try to relate the fundamentals of those principles or the parameters electro acoustical parameters and try to relate that with the architectural design of electro acoustics.

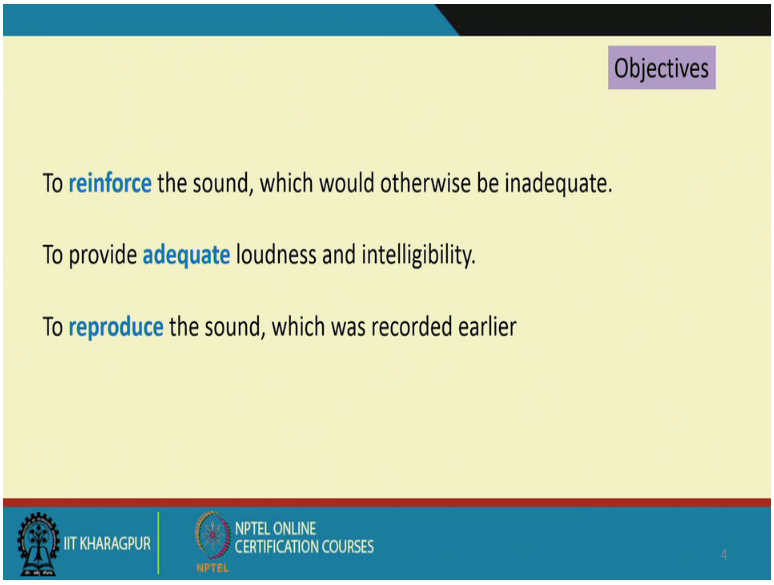
(Refer Slide Time: 01:32)



Now, basically where I say about the electro-acoustic it is kind of a sound reinforce system. The sound reinforce system is sometimes when the a particular hall or particular area is too large or sometimes I am going to produce some kind of a pre recorded kind of a voice or music we need to help we are need to take help of the electro mechanical systems, something like a loud speaker the microphones and all.

In fact, today this NPTEL course or may be this NPTEL course and all everything is actually a the game of a electro acoustical part. I have a speaker with I mean the microphone with here which is a collar microphone kind of a thing and that is going to produce the sound to you through some electro electrical pulse and then finally, my sound is transmitted or the captured by this particular this collar microphone and it is sending some kind of electrical pulse and finally, when you reach into your the environment or the your room or in your laptop or may be any kind of a computer device or maybe it is your mobile. It is actually again translate that electro I mean electrical pulse to a sound energies also. So, this is the brief definition of the sound reinforcement or the sound electro acoustical systems.

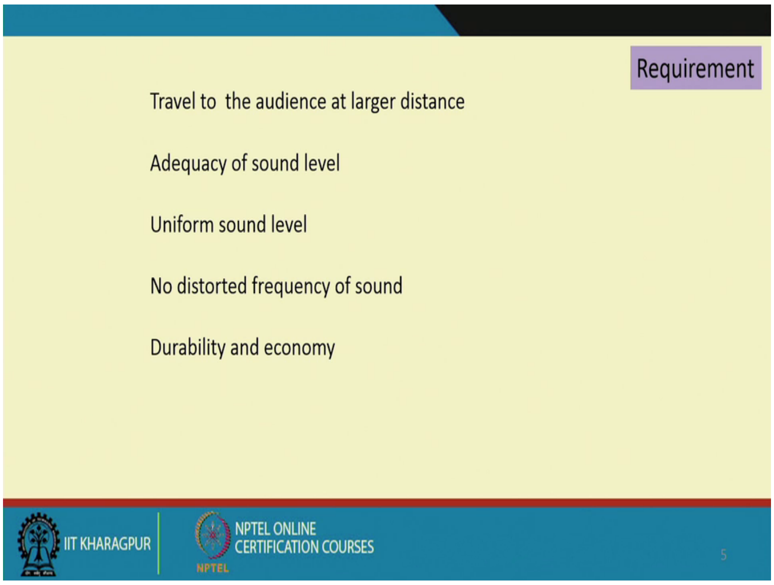
(Refer Slide Time: 03:02)



Now, what are the objective of this electro acoustical systems? The there are three basic objective of the electro acoustical systems, one is reinforce the sound. I just I have told you if the size of the this a vertical hall is very large or there is a huge amount of audience very high capacity of the volume I have to take care, sound probably in probably it will be in adequate I mean the only the voice or any kind of a music which actually going to play in the stage which is may be very weak for the rear seat are some portion of the auditorium. So, you need to reinforce the sound by some kind of a amplification.

Then the we have to provide some kind of the adequate loudness or may be the adequate intelligibility where we can actually hear the sound actual sound and the frequency of the sound without any kind of a distortion and the loudness should be adequate. And, sometimes we need many times we need the reproduce the sound which was recorded earlier some music or maybe some kind of a the voice or some kind of the performance which has been recorded earlier and that that can be reproduced in a some different locations. So, for that electro acoustical system is required.

(Refer Slide Time: 04:27)



Now, in this when we going to deal with some kind of electro acoustical systems various component of it we have some of the requirement. In requirement from that point requirement point of view of the first requirement the sound should travel to the audience of the in large distance, that is the one of the basic fundamental requirement of electro acoustical systems. Otherwise perhaps electro acoustical systems was not developed.

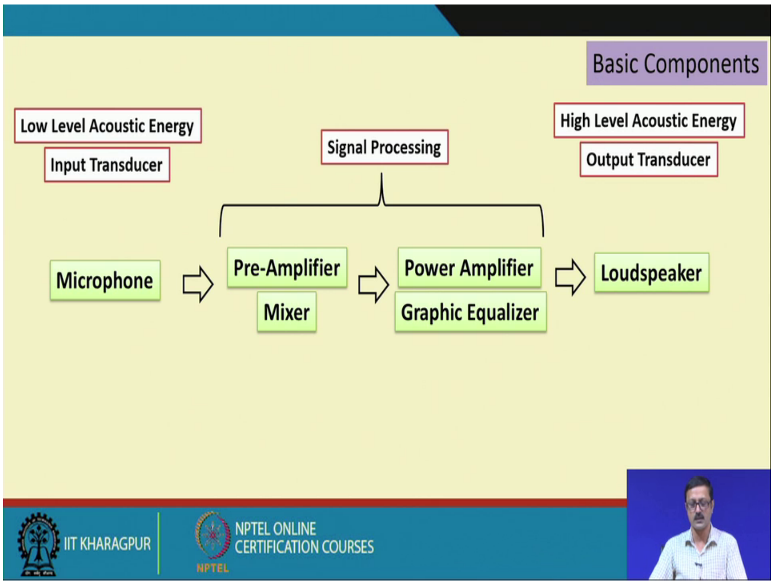
And, the second requirement is the adequacy of the sound level sound level has to maintain a kind of a adequate sound level in every part of the auditorium not only in the front or may be only in the back part, in the sides and also in the middle part of the auditorium. The uniform sound level which is also a part of are kind of the adequacy a point of view we can just the uniformity. So, there should not be very high sound level in some point and very low sound level in some other point. So, should have a flat kind of a character.

The fourth one is very important there should not be any distortion of the frequency of the sound ah. So, the sound frequency which comes out from any kind of a musical instrument which comes out from some kind some someone’s voice should not be started the same frequency and as you know the frequency is actually give you the character of the sound. So, that frequency should not be distorted. Suppose, a tabla is playing over here through that sound should be a bass or those kind of a frequency level and may be a guitar or may be any other kind of a instrument should not or may be a piano should not distorted the voice after this amplification or the reinforcement.

And, the finally, which always a architect deal or any kind of a engineer deal which is a system durability and the total economy of the systems that also we have to check from the various properties of the system component.

So, next we will see the what are the basic component of the system some this your acoustical systems.

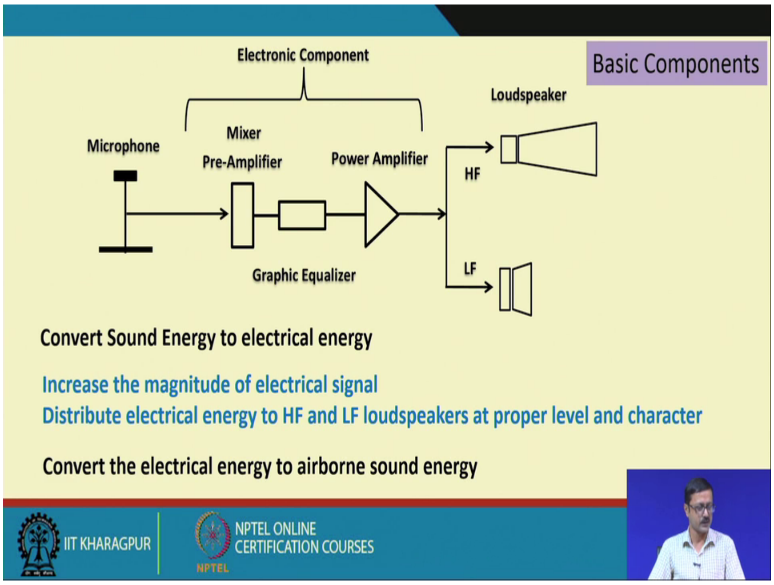
(Refer Slide Time: 06:47)



So, if I see in this particular slide I have classified this system into three major part. The initially it is a low level acoustical energy which is provided by some kind of a performance or may be some kind of a speech has to taken into some kind of a input transducer and then this particular thing the particular acoustical energy has to go through some kind of a processing which is called the signal processing and then the high level acoustical energy has to be reach to the audience through some kind of the output transducer.

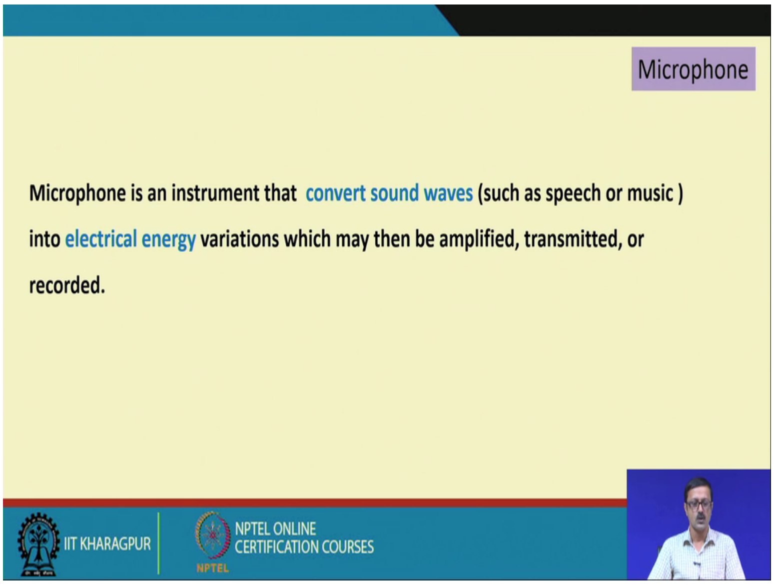
And, this input transducer are the low level acoustical energy can be taken through the microphones which I have just now told you that this I have also a microphone only and then this particular microphone then going to the town from the microphone captured sound from the microphone when to the signal processing unit which has basically two power; one called the pre amplifier or a mixer and another one is called the power amplifier or the graphic equalizer and the finally, it goes to the loudspeaker which is output transducer and the role of the loudspeaker is just translate the electrical signals to a sound signals once again.

(Refer Slide Time: 08:15)



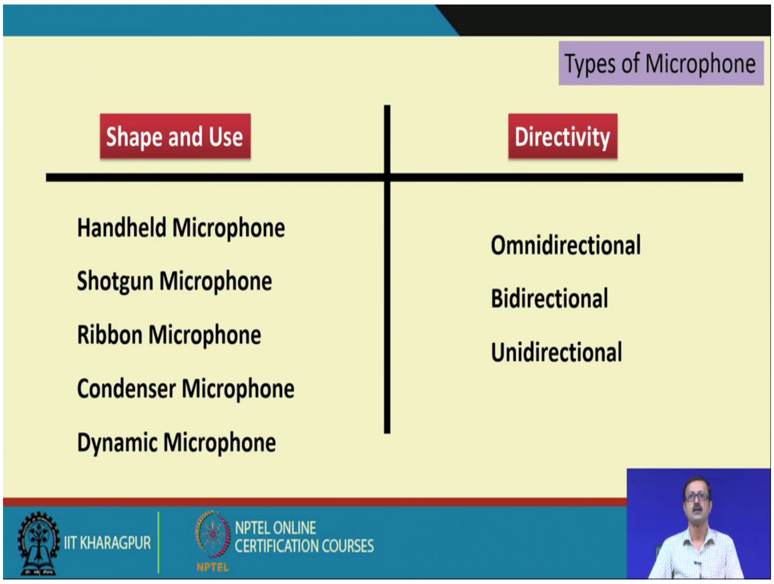
I have given this particular slide is some pictorial presentation. So, with that I can again re state that particular functions or the basic component. Microphone which convert the sound energy to electrical energy, then there are lot of electronics arrangement where the graphic equalizer, the power and the pre-amplifier has to make a common role which is comes under some kind of the signal processing kind of thing where they will actually separate out the frequencies HF and LF are the high frequency and the low frequency sound to the high frequency and the low frequency loudspeaker and finally, the loudspeaker will convert the electrical energy should to airborne sound energies also.

(Refer Slide Time: 09:00)



So, the first component if I again go back, so, the first component is this particular the microphone this microphone is the first component. So, let us discuss to one by one of this component and what are the various, the requirement and what are the various types available ah. The microphone again what we have a understand that is convert the sound energy or the sound wave to electrical impulse.

(Refer Slide Time: 09:30)



And the types of if I say the types of sound sorry the microphones or how I has divided into two type of that classification. In the first type of classification I can say it is some kind of within shape and the use point of view there are classification like handheld, shotgun, the ribbon or condenser or dynamic kind of a microphone. And, if I went to some kind of a directivity point of view the how the microphone is behaving and how it is going to captured the sound and from which direction actually, then it has a omni-directional, bidirectional or unidirectional; this three categories of the microphones are available and that is the classification based on the directivity.

So, let us go one by one on see how this are actually look like.

(Refer Slide Time: 10:24)

And, the shape point of view and the use point of view this handheld kind of microphone which you must have seen in the hand of reporters, in some kind of entertainment channels, they put in front of some somebody's face and the gives some kind of a bites the that particular the journalist and they use this particular type of handheld microphone kind of a thing ah. There are two types of handheld; one is with cord or sometimes it is without cord are the cordless kind of a microphone are also available.

In the next one is a shotgun microphone and that is extremely directional microphone, but; that means, it is actually catches the sound from a very the distinct the direction point of view. So, if that particular direction has changed from some angle it has a very poor kind of a output, it will show some kind of a very poor output. It is very popular in the movie set and particularly the news televisions or news studios, TV a news studios where a particular shotgun kind of a microphone is held in a particular direction or particular place and the speech or may be some kind of the dialogue can be captured.

(Refer Slide Time: 11:49)

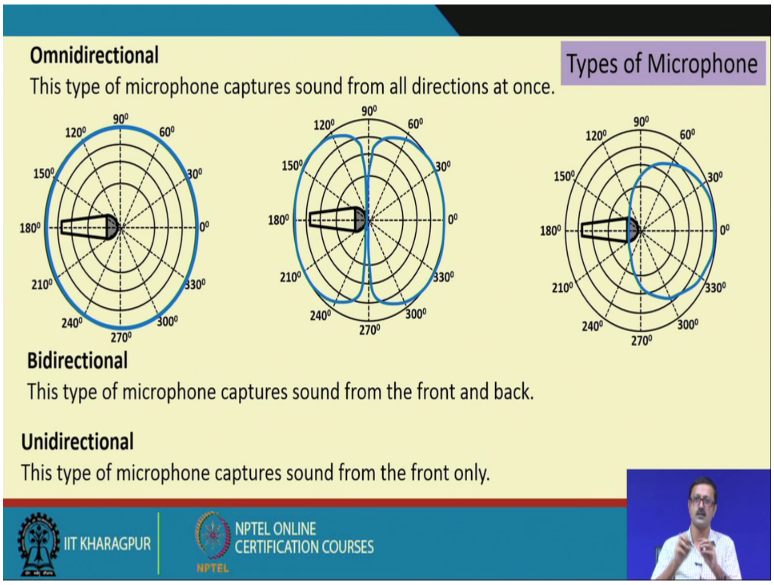
The next one is ribbon microphone which actually use for the speeches which actually use for the radio stations which this ribbon microphone are bit older version and this modern days we have some better versions of this particular microphone and it was used in kind of announcement or those kind of a thing. If few hap perhaps seen this kind of microphone in the telecasting when they actually telecast the videos for the some the sports event like cricket or may be football in that particular both where actually the commentators both where they actually sit and give the running commentary of any kind of a sports event they use this kind of microphone. Radio stations also for some kind of announcement in the railway stations or may be any airport they use this kind of microphone, ribbon microphone.

Then the condenser microphone again it is an old kind of version of the condenser microphone which is a very wide range of the directivity and this actually captures the vocals and the music of different area if must of we have seen in a stage performance musical performance like in a stage, in auditorium this condenser microphone are each given to far for the each the vocal or the musical instrument and it captured the sound from them.

The last one is called the dynamic microphone which is mostly used for the instrument like the guitars or drums again this has a wonderful directivity and this is a kind of a replacement of the condenser microphone to this dynamic my microphone nowadays and the again I must say this dynamic microphone is the that what we have seen the very first that is the that one handheld is one type of the dynamic microphone kind of it. So, those are the various classifications of the microphone from the virtue of the shape and the use.

So, let us see the what are the types available from the directivity.

(Refer Slide Time: 14:05)



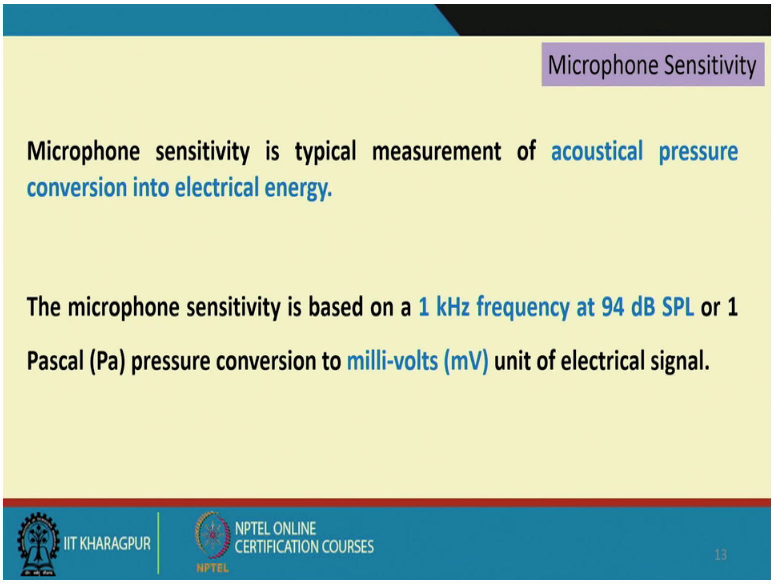
So, the first one is the omnidirectional, where I have se I have plotted a diagram with a center point I place that particular microphone and this blue circular line gives the directivity it has. So, it send that it has a almost the equal directivity which is the and it is capture the sound from 360 degree. So, that is why it is called the omnidirectional kind of a microphone. And, the bidirectional microphones are those which has a directivity only the two opposite directions. So, one may be in the 0 degree direction and another one is the 180 degree direction.

So, if you see the blue lines over here in this particular diagram. So, from that you has so, the offset from the towards the 90 degree and the 270 degree the capturing potential is little less. So, it is the it is the property of this bidirectional kind of a microphone. The third one is the unidirectional type of microphone where it is actually capitulate the only from the one location only from the front location. So, if it is in the 90 degree orientation are 180 or may be in the 270 degree orientation some sound comes from this side or may be from back side or from these area it does not have that much of a fifty bit.

So, sometimes we use the unidirectional microphone just to avoid some kind of noise maybe background noise or may be noise from the sides. So, only when you focus a particular the source of the sound and you know that particular source of the sound is located it the particular the typical point, then it is better to the unidirectional kind of a microphone.

Now, next talk about some kind of the what are the different properties of the this microphone.

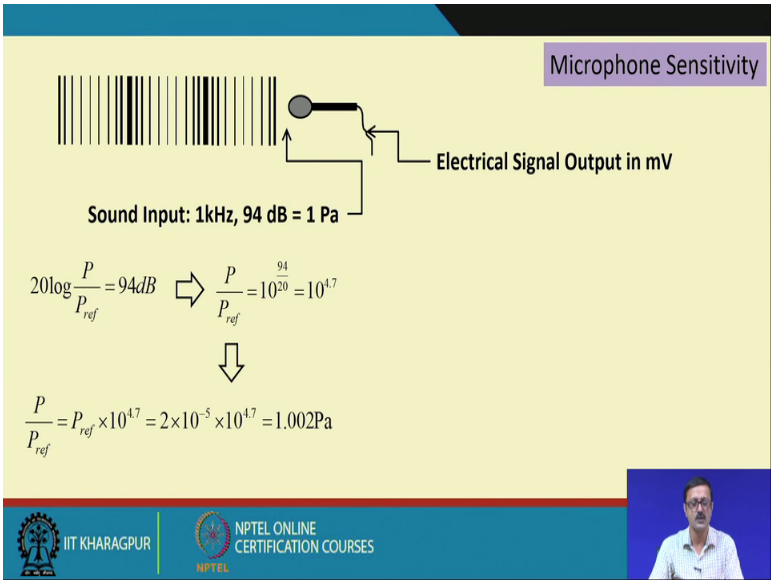
(Refer Slide Time: 16:03)



The first property of the microphone is called the a sensitivity of the microphone how the how thus microphone is sensitive how much it sensitive. So, it is relate it actually translate in a the definition wise that how much acoustical pressure is converted to this particular by this particular microphone some kind of a electrical impulse because I have already told you, what is the duty on the role of a microphone it is captured the sound and then it translate the sound that particular a mechanical the vibration of the sound to a electrical impulse.

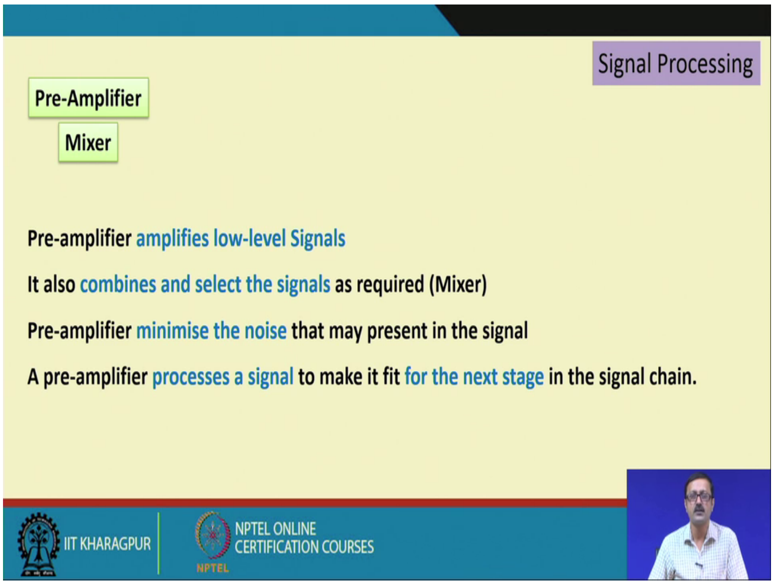
So, the one kilohertz frequency of the sound at 94 dB SPL or 1 Pascal pressure sound pressure is the bottom or the decome level and from that how much it is converting in millivolt unit in electrical signal is sensitivity of a microphone. So, some microphone may provide much more millivolt and some microphone may not provide that much from that point of view I can give some kind of a stratification of the microphone sensitivity, but the input is 1 kilohertz with 94 dB sound which is equivalent to almost 1 Pascal.

(Refer Slide Time: 17:19)



So, I have given a pictorial diagram. So, suppose this is the audio wave or the sound wave which is actually mechanical wave it is the compression read of fraction it is come to this particular microphone. So, the input has to be 94 dB at 1 kilohertz and that equivalent to 1 Pascal. So, I have just calculated that the this formula which 94 dB is the it is the pressure, I want to find out it is 20 log and then if I just rewrite this equation then I find that this P which is equivalent to 94 are which produce the 94 dB is nothing, but are one almost 1 Pascal. So, a 1 Pascal sound pressure is generated very near to the microphone and you find out how much is the millivolt output from some kind of the electrical impulse recorder you find out what is the millivolt output and that will be the sensitivity of the microphone.

(Refer Slide Time: 18:21)

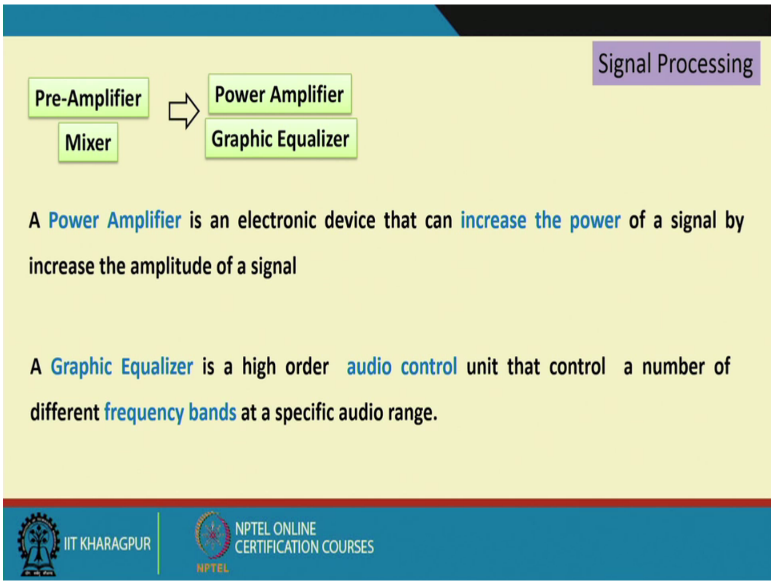


After the microphone the next stage what so, what microphone does is that it has actually converted it actually converted the signal which is sound or the mechanical signal to a is acoustical signal to a electrical impulse. Now, it will go to the some signal processing which is the secondary are the middle unit of my the electro acoustical systems. So, it has first has to go through the preamplifier which is also called as any mixer.

So, it is mix, first of all it is going to mix some kind of frequencies combined some kind of frequencies why because there may be lot of the vary I am lot of the more than one output. Suppose, there are some mis instrument some vocals and some other people may give some kind of a speech. So, in a stage or in a music recording room there may be different musical instrument. So, you captured different the sound are the electrical impulse by virtue of different microphones and then there is a very low level of signal amplification very slightly low level of signal amplification it will do.

Then, in this particular process of the preamplifier it will also minimize the noise if there are some kind of a noise which is not wanted for the final delivery. So, those noise has to be minimized by virtue of some kind of a screening and filtering in this particular preamplifier system.

(Refer Slide Time: 20:09)

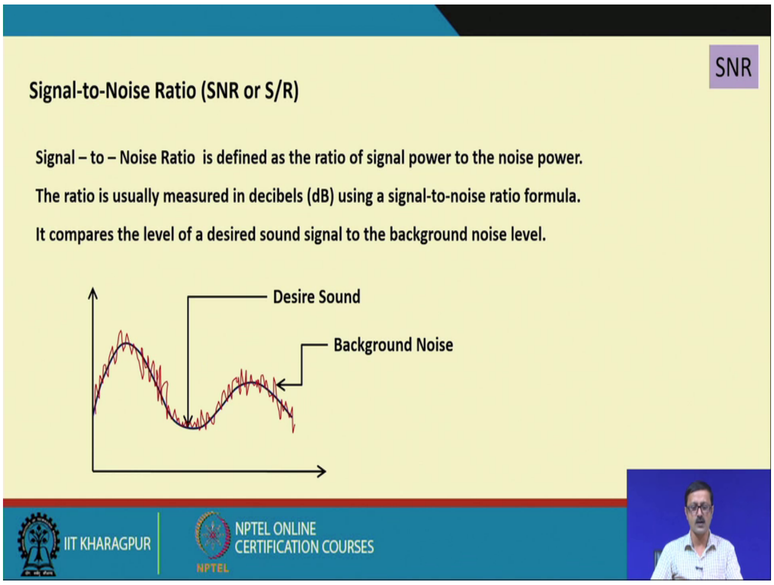


And, this particular mixing noise minimization and the amplification slight amplification I must say that will be given to the next part of the signal processing which is called the power amplifier or it is also known as sometimes graphics graphic equalizer.

Now, they it has it has major majorly two jobs. This power amplifier power amplifier as the name suggest it will amplify the power amplify the increase the power of the signal and then it will which is one of the need for the electrical sorry the electro acoustical systems which is going to reinforce my sound and the graphic equalizer controls the audio, total audio and different frequency bands and everything they will give you kind of a overall control by virtue of some kind of you want to produce some kind of a music suppose you want to put the tabla sound little low and the guitar sound little high and the voice of a particular singer is the further more high or low whatever may be the situation or a director music director thinks, by virtue of that particular thinking we can use some kind of the frequency band control and the equalization of this particular sound.

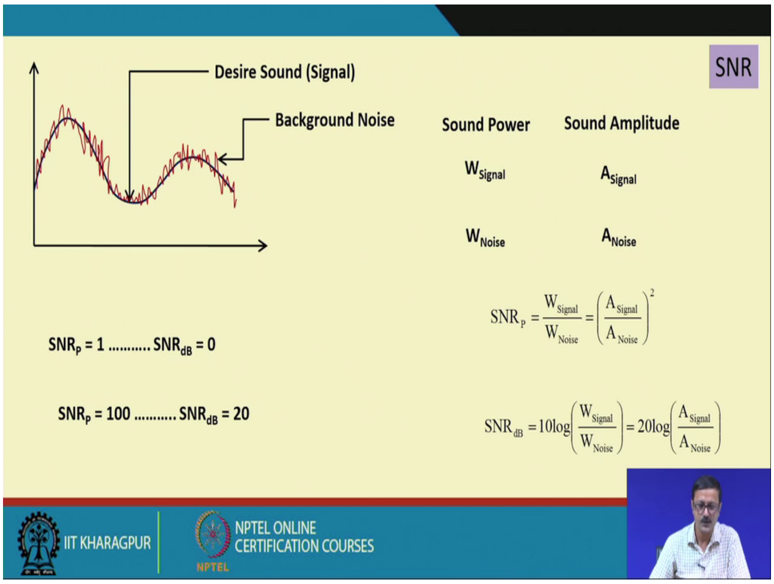
So, that is one of the part one of the role or one of the component that will actually perform in the power amplification.

(Refer Slide Time: 21:28)



So, after this power amplification was going on so, there is a kind of a another ratio comes or another parameter comes which is called a signal-to-noise ratio because there are some noise which I have shown here by virtue of some blue sorry the red lines which is a noise, but desires sound is this path that has to be taken into accounts. So, I have to actually take out this particular noise and then the desire some has to filtered.

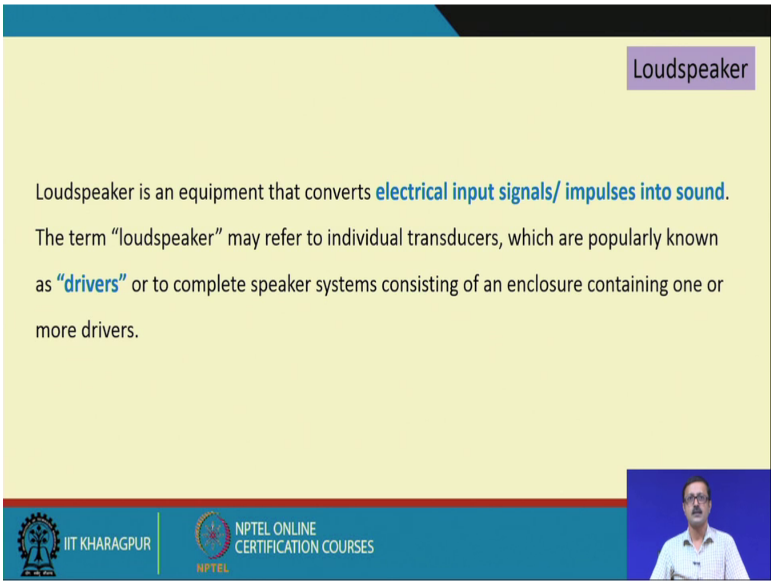
(Refer Slide Time: 21:56)



At for that the signal-to-noise ratio has been the taken as a one of the basic parameter where it has been right as from the power point of view W signal by W noise, where the

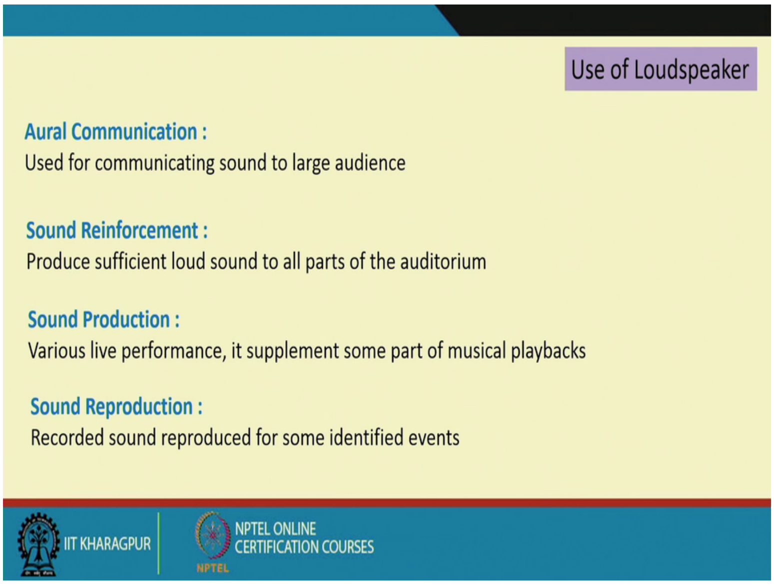
Ws are the power of this particular signal and this noise or sometimes it may be rewritten as a dB scale when it is SNR is a signal to noise ratio in dB which is 10 log of that on it can be also rewritten as a amplitude functions also when it will come on to I mean the it is amplitude square is the way it can be written. So, I can say that when the from the power point of view SN ratio is 1 so, its translate as a dB of SN ratio of 0 and when it is suppose 100 from power point of view it is goes like 20.

(Refer Slide Time: 22:49)



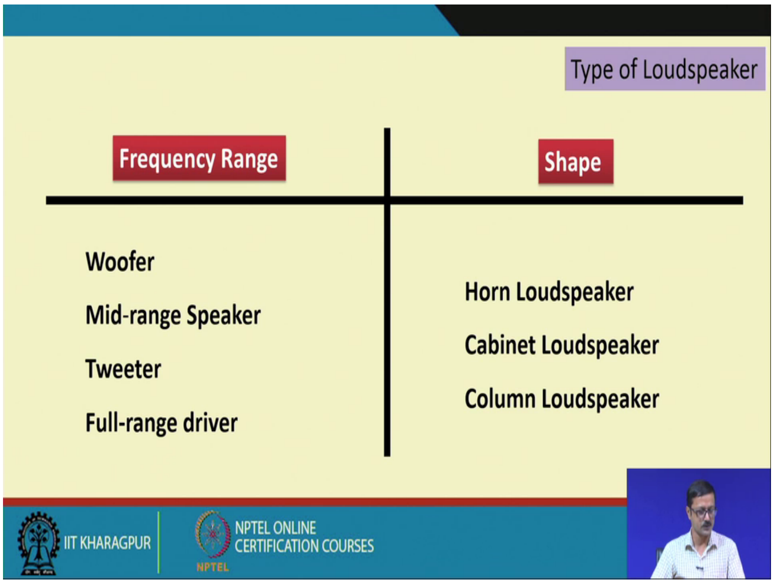
So, after this the signal processings and all we will let us let us see what are the loudspeaker. Loudspeaker is the final the final part of this electro acoustical systems where a particular electrical energy is now is ready to transform it is already amplified and it is ready to transform to sound in a come back to the sound energy again in and it is now like to propagate and it is called a driver they this calls so loudspeakers or called final driver of the system.

(Refer Slide Time: 23:28)



So, the what are the use? There are four typical use, it is aural communication we use the loudspeaker. We use loudspeaker for the sound reinforcement, we use sounds the loudspeaker for sound production, for some kind of a live performance and some's many a times we use this is for some kind of a reproduction where a already recorded sound is reproduce by the loudspeaker.

(Refer Slide Time: 23:56)

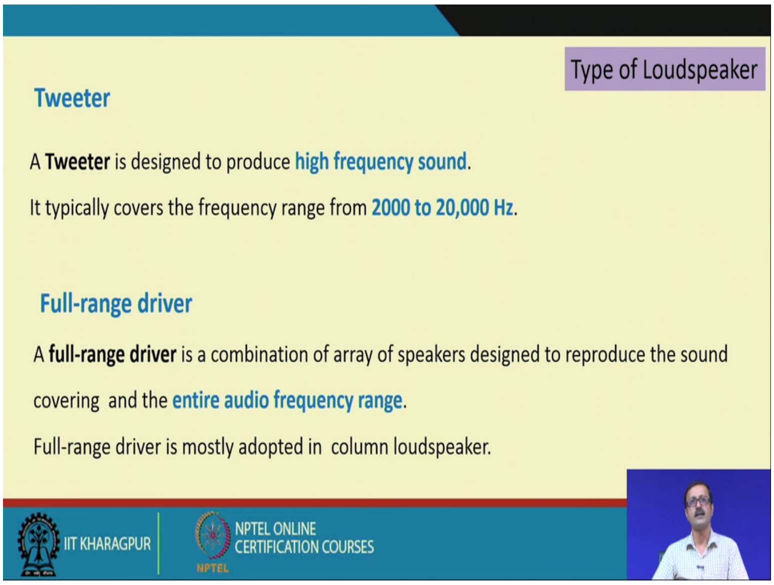


What are the types of the loudspeaker? Again, I have classifier into two categories from the frequency point of view it is having the sorry woofer, the mid-range speaker, the tweeter and the full-range device and from the shape point of view it is can be classified as the horn, is cabinet loudspeaker or maybe the column loud loudspeaker. So, let us go one by one.

(Refer Slide Time: 24:21)

The woofer is a kind of a loudspeaker which actually very delivered the low frequency and bass sound which is approximately 20 to 200 hertz and they are further classified as the pre-woofer or may be the subwoofer like that. And, the mid range speakers has them suggest is taken care of the mid frequency level which is 250 or 250 to 2000 hertz and it is also take care of those particular mid frequencies and the delivery properly , but this may not be very much effective for the low or high frequency is also called squawker.

(Refer Slide Time: 25:02)



And, the final one is the tweeter which is the actually design the high frequency sound for design for the high frequency sound which goes with the 200 to 2000 kilohertz sound level also and full-range is for the audio full-range from all the sound level from the mid to high and also the low frequency sound.

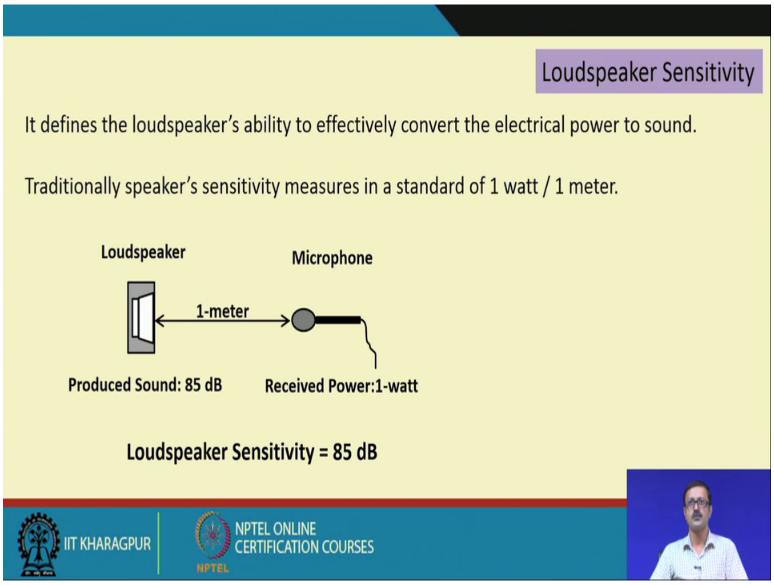
(Refer Slide Time: 25:27)

So, this names if you go back if I go back to the names the barking of dog is called woofer. So, it is ah, that is why this low frequency, barking of dog that is why it is called woofer. The mid frequencies are squawkers which is the squawk you know that that is sound is kind of a mid frequency sound and tweeter that this birds are tweetings and all these are the high frequency of the sound that is why they are called the tweeter kind of the loudspeaker.

(Refer Slide Time: 25:57)

So, this is the from the shape point of view these are the horn loudspeaker which is very popular for the announcement are those kind of a thing. This is the cabinet loudspeaker small and miniature versions cabinet and there are 2 – 3 type of loudspeaker can be placed together and there may be a column loudspeaker where there is a series of low or high frequency or a mix kind of a things also may be placed in a series in a vertical series.

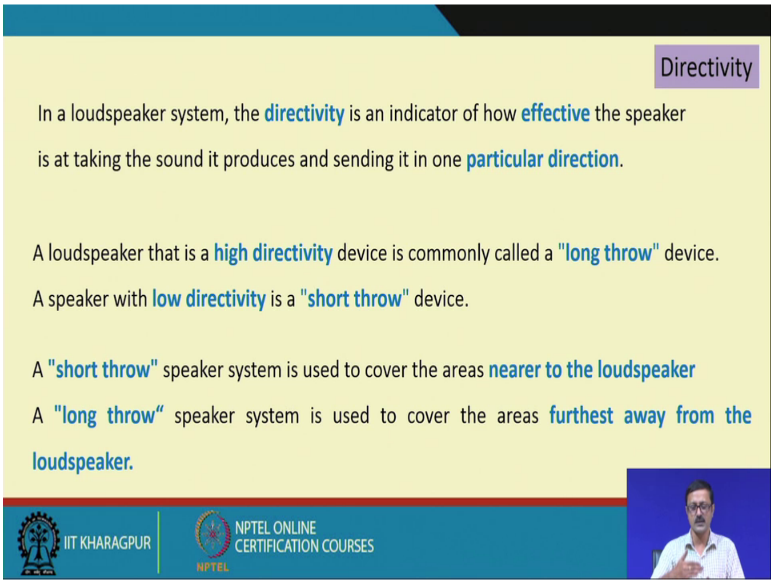
(Refer Slide Time: 26:25)



Now, similarly like we deal with the microphones the loudspeaker sensitivities also one of the important things, where it can be defined as 1 watt 1 meter kind of a seen are 1 watt 1 meter kind of a thing; which actually from 1 meter if this power received from in this microphone is 1 watt 1 meter from the loudspeaker and suppose this is producing 85 dB sound then I can see this loudspeaker sensitivity just simple 85 dB.

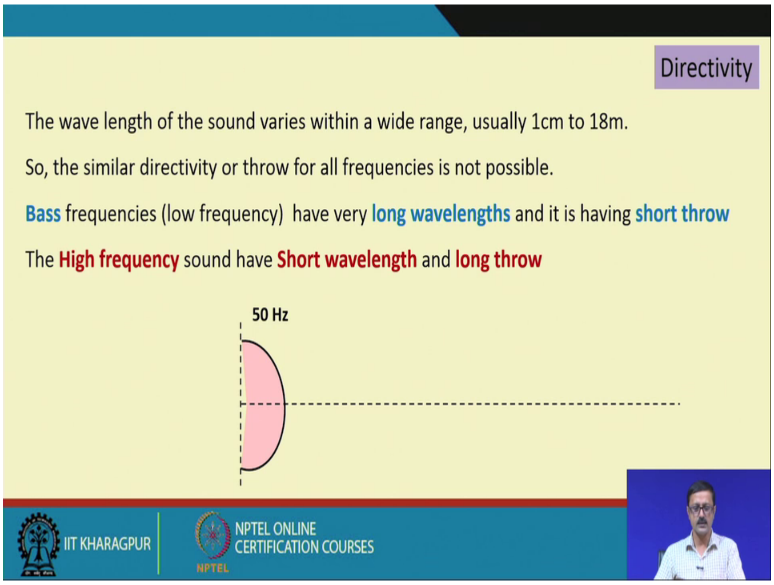
So, how much I am receiving that should be now fixed, that is, 1 watt and to receive one watt what is the dB level of the this the loudspeaker at a distance 1 meter.

(Refer Slide Time: 27:11)



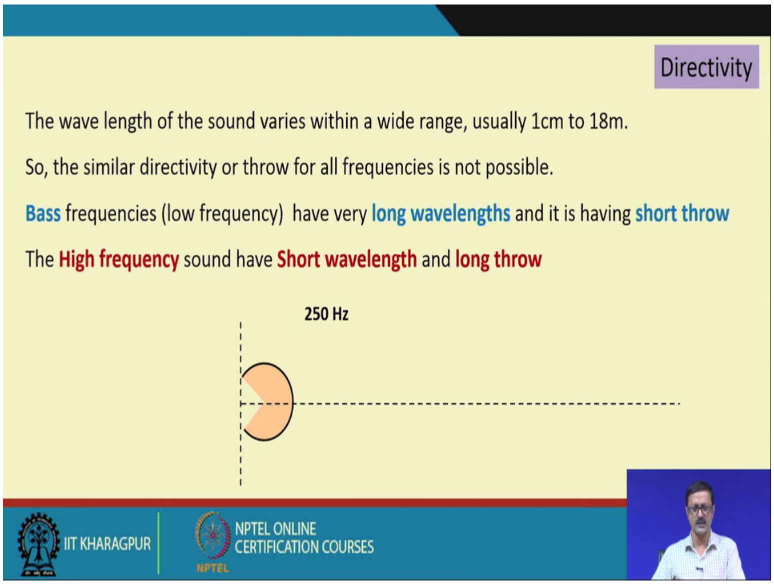
And, the next one is the directivity of the sound or the directivity of the loudspeaker, where loudspeaker actually provide kind of a directive sounds in a particular direction. And, from the directivity point of view it is a throw, sometime it is a long throw or sometimes it is a short kind of a throw. So, as you know that the long throws or go nearer to the loudspeaker and the short throw goes to the nearer to the loudspeaker and the long throw was very further away.

(Refer Slide Time: 27:42)



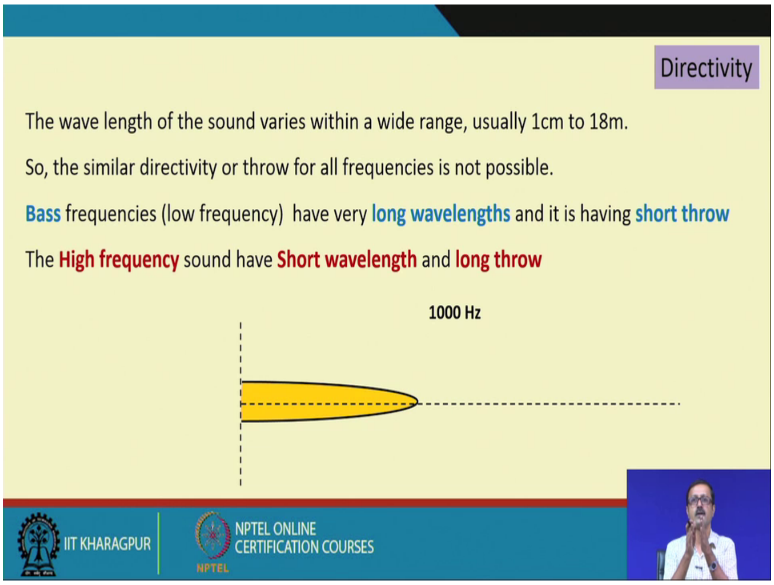
So, from this point of view it has been seen that it is depend upon the wavelength of the sound and the wavelength of the sound when it is a bass are the low frequency sound which is having a long wavelength it has a short throw something.

(Refer Slide Time: 28:01)



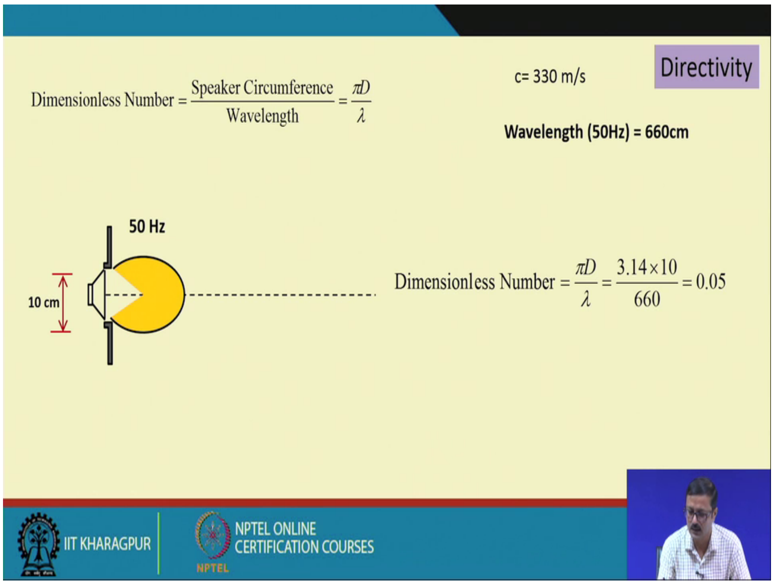
Like this 50 hertz as a very short kind of a throw and then again if I increase it little bit little bit x I mean little bit higher throw, but it is the width narrower width narrow width and the high frequency if you go to the high frequency sound it will be give you a more or shorter a wavelength and it will give a more throw.

(Refer Slide Time: 28:20)



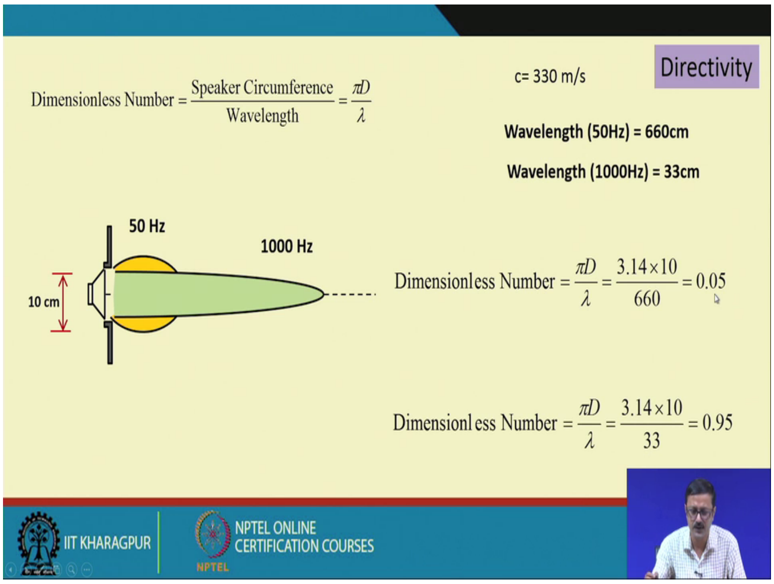
Suppose, if you go to the 500 or 1000 it will be narrower it will be narrower, but the throw length will be very high.

(Refer Slide Time: 28:27)



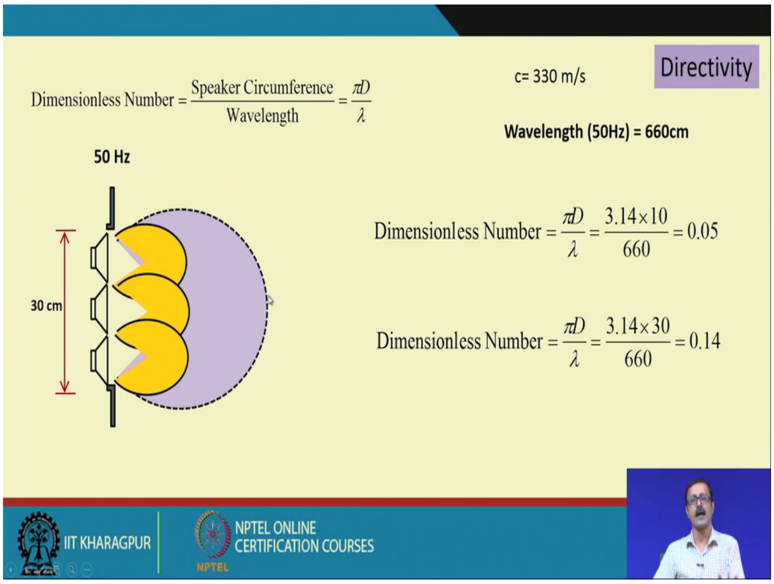
So, something like this. So, these a also has to taken into some mathematical model cal kind of a calculation with by merge of some kind of a dimensionless number. The speaker circumference by the wavelength has are they have computed has a dimensionless number and they have seen that suppose, if I take the velocity of sound is 330 meter per second and the wavelength for 50 hertz is 660 centimeter and if you 10 centimeter the aperture or the dia of the this particular speaker, so, if I compute the this dimensional number pi D by lambda is 0.05.

(Refer Slide Time: 29:10)



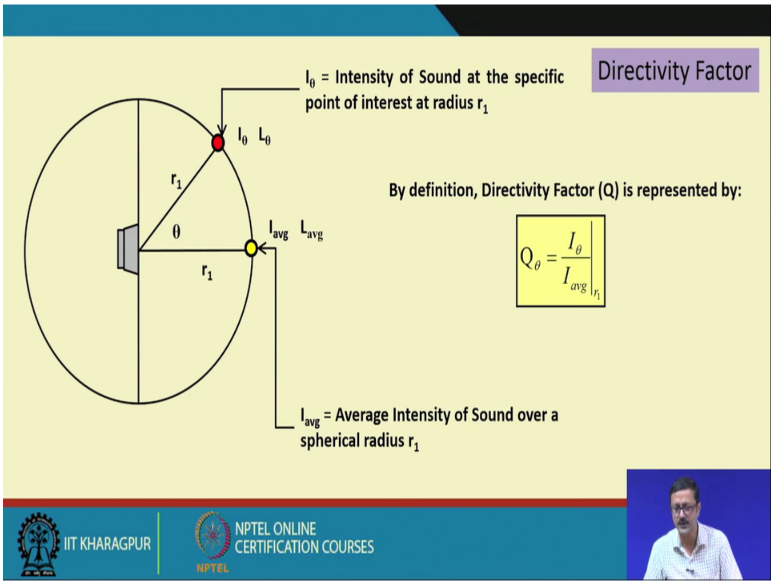
But, for high frequency sound it is 1000 hertz, the 33 centimeter. So, this particular becomes this particular dimensional number become 0.95 shows it has a higher amount of throw.

(Refer Slide Time: 29:25)



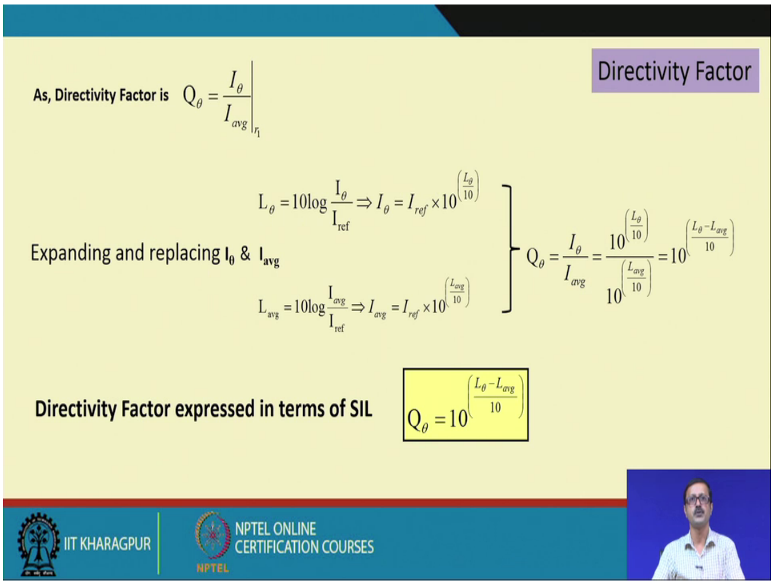
So, now if I want to go with the 50 hertz you see which is having a low amount of throw and I if I increase the number of speaker in a the horizontal or may be a vertical distance. So, I use three such 10 plus 10 plus 10, 30 centimeter. So, for each individual it has a dimensional dimensionless number is 0.05. Now, if I use three then the dia is increase by 30 and then if you recompute with a same wavelength now it is become 0.14. So, this the purple colour bulb will be the actual throw or the actual directivity of the three, this three.

(Refer Slide Time: 30:04)



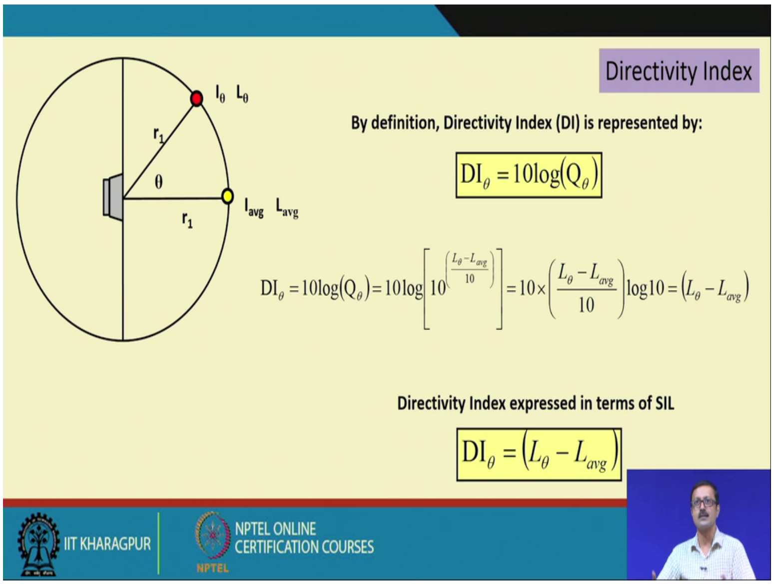
So, the directivity is again computed by sound factor called directivity factor. So, from the speaker in a very straightforward 0 degree line, suppose at this particular yellow point I got a the sound level as l average with a sound intensity of I average, but if I go some theta angle with a same radius r 1 this is red I got the red point and I got the intensity as I theta and L theta then by definition the directivity factor Q theta means at particular angle theta is called I theta by I average at a particular radius r.

(Refer Slide Time: 30:50)



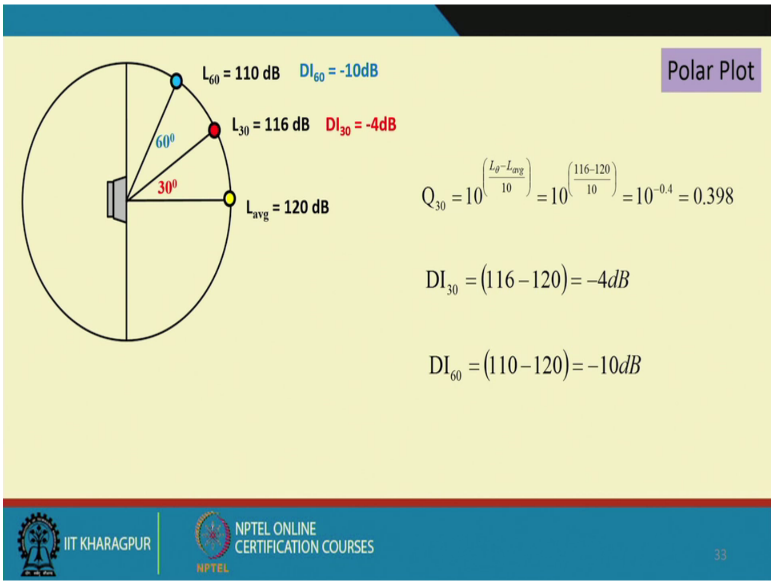
So, is particular computation if you can do, now the I theta can be rewritten as this I format and the I can be written as that this way the I reference into 10 into 10 to the into 10 to the power L theta by 10. So if I use this I theta and I average and if I replace this by this level sound pressure level or the sound intensity level I give this as a final result. So, the in terms of the SIL sound intensity level Q theta can be rewritten as in this yellow box format so, 10 to the power if this particular the L theta minus L average by 10.

(Refer Slide Time: 31:38)



So, next is the directivity index directivity index is DI of that particular theta is nothing, but the 10 times logarithmic of this directivity factor Q theta and if I re open it this particular equation it is nothing, but the L theta minus L average. So, whatever may be the level of here and whatever may be the L average of here the difference between them is the directivity index.

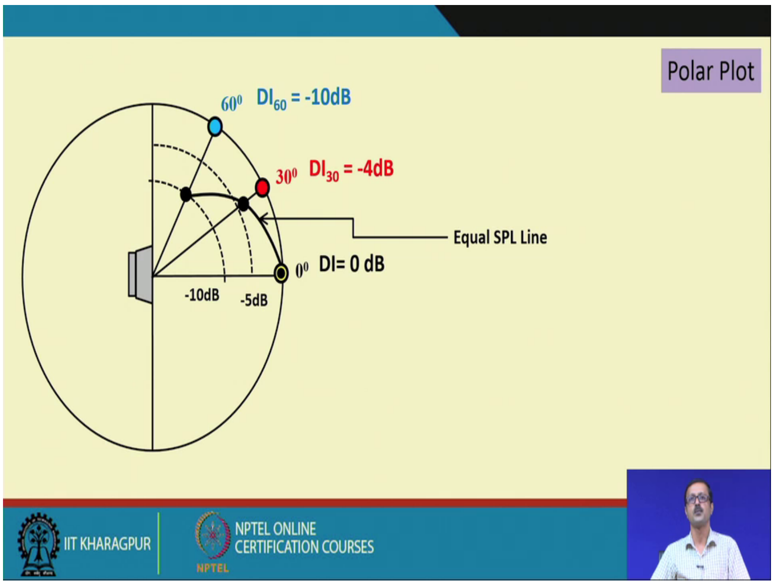
(Refer Slide Time: 32:13)



So, let us go to a small mathematical understanding where suppose in this particular 0 degree line I got a 120 decibel is the L average and if I move circular in a circular path without change in the radius from the loudspeaker at 30 degree I got 116. So, you are directivity index is a minus 4 dB because 116 minus 120 is minus 4. Similarly, in L 60 degree it is suppose 110, so, it is minus 10 dB.

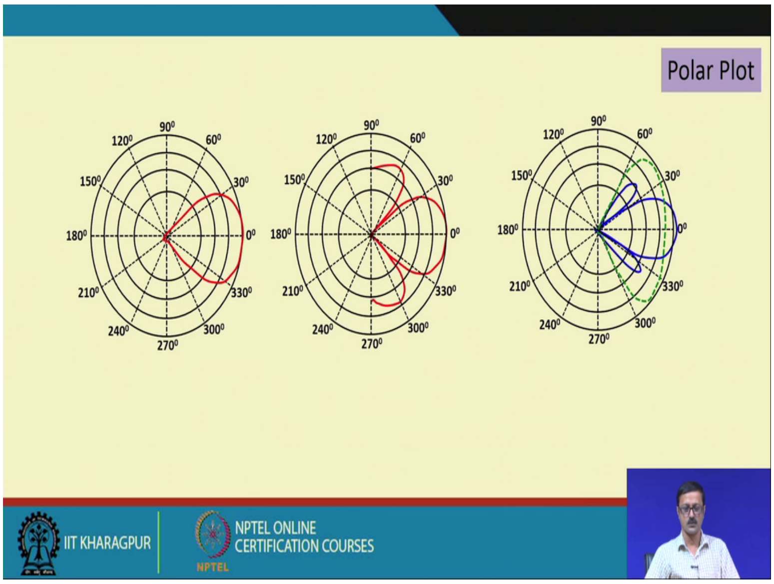
So, what it can give me is that in the same radius if I move gradually the decibel level is slower down.

(Refer Slide Time: 33:03)



And, if I now go with this, so, at particular 30 degree it has minus 4 and this is minus 10 so, I can say a I can draw a concentric circle of minus 5, minus 10 dB something like that and then I can say this equivalent sound level of this is nearly somewhere here and equivalent sound level of this yellow which is in the 0 degree line is nearly here in the sixty degree line because it is minus 10; minus 10 from the this particular and this is minus 4 and finally, if I draw this in a curve I mean draw this particular points in various circular segments in curve I can I can actually draw equal SPL line and this is called the polar plot of the polar plot of the loudspeaker.

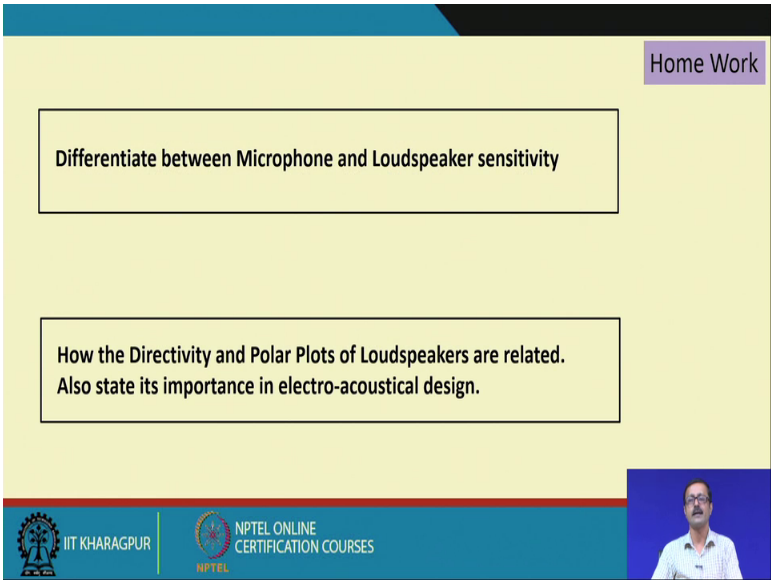
(Refer Slide Time: 33:55)



So, there are this kind of polar plot can be drawn. So, in the left side this is the this is a single polar plot are this particular microphone I am sorry the loudspeaker has a this kind of a directivity and this is the equal SPL contour this is a maybe two or three microphones or may be a single microphone has this kind of a direct little bit of complex directivity, where these are the polar plot of the watt particular loudspeaker. And, this loudspeaker has I have drawn blue and green. Suppose, this blue and green or for may be two different frequency suppose this is some high frequency and this is suppose some kind of a low frequency kind of a directivity and the equal SPL plots.

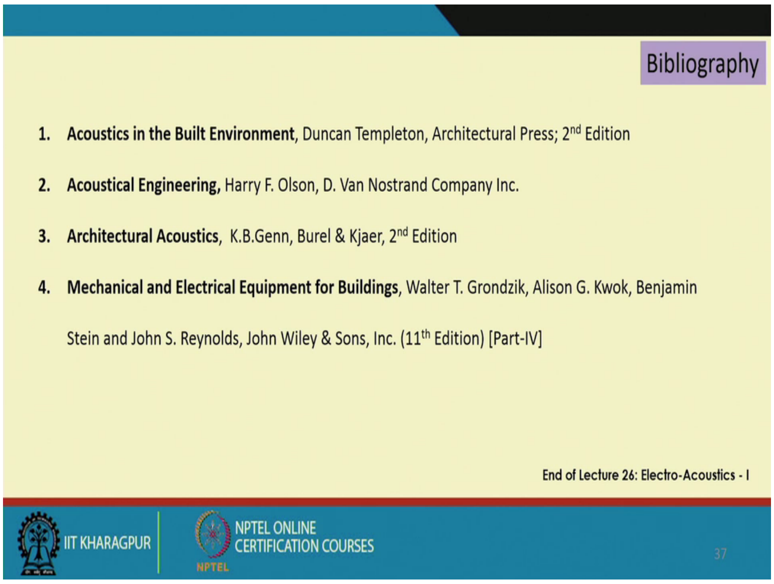
So, this equal SPL plots comes from the directivity which is a one of the significant property or the parameter of the loudspeaker which we will again take into the next chapter next discussion lecture number – 27 for further details.

(Refer Slide Time: 35:01)



So, this lecture ends here. So, let us take some the homework and this two homework I have design it is not a mathematical it is just kind of a discussion or this kind of a understanding. So, can you differentiate between the microphone and the loudspeaker sensitivity and these are little that is a little difference between them the loudspeaker sensitivity and the microphone sensitivity. And, you can another one is the how this directivity of the polar plots or the polar plots of a loudspeaker related, directivity and the this polar plots how they are related and what are the importance of this polar plots do you think for the electro acoustical design.

(Refer Slide Time: 35:45)



So, that is ends my lecture these are the sum of the books I have referred for this lecture and next lecture in that lecture number 27, will go with the some acoustical design principles.

So, thank you for joining us and let us move to the next lecture.