Basics of Noise and Its Measurements
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Lecture – 21
Classification of Microphones by Application

Welcome to Basics of Noise and its Measurements. In the last two classes, we have discussed the classification of microphones on the basis of their operating principle. Today, we will continue that discussion, but today instead of talking about the operating principle, we will look at microphones and classify them from the (Refer Time: 00:37) point of their application areas. There could be a situation where you have a lot of reflected sound, there could be a situation where you have a sound coming from a source and it is readily propagating in all directions and you want to capture that sound, there could be a situation where you have a planar wave front coming.

So, these are several categories of applications and what type of microphone you use, it depends on the understanding of our microphones and their classification from the standpoint of applications. Before we discuss this thing, what we will talk about is this notion of directivity. So, maybe half of this class I will discuss about directivity what it means, and then we will discuss different types of microphones based on application.

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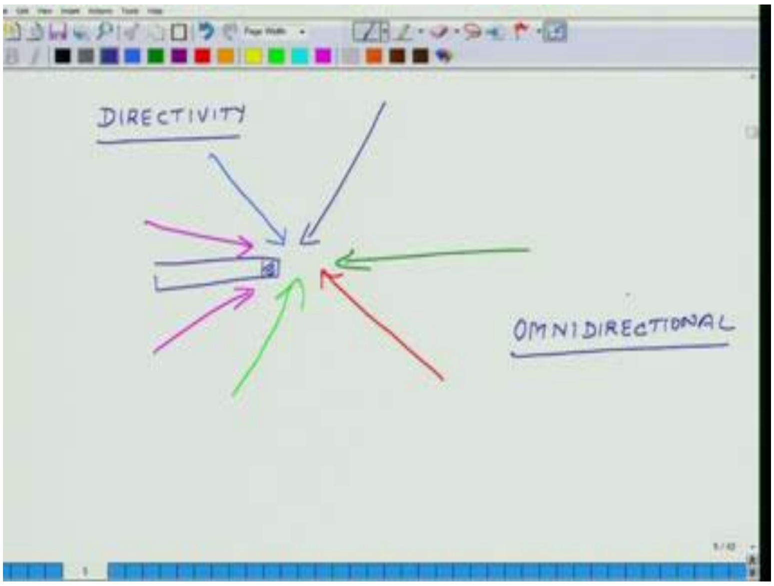

What is directivity in contexts of microphones? What it means? A microphone, suppose, you have this microphone and sound can be coming from all sources. From different directions different types of sound is coming, and if the microphone can sense all types of sounds which are coming from all directions with uniform amount of sensitivity, with same amount of sensitivity and accuracy and resolution. Then that microphone is known as Omnidirectional. A microphone which can hear all types of frequencies coming from all directions with same amount of sensitivity, that type of microphone is known as an Omnidirectional microphones.

In general, microphones are more sensitive to one particular direction, for instances there may could be a microphone which is more sensitive to sound coming from the front side, I can design a microphone which is more sensitivity to sound coming from the back side or from 45 degree side and so and so forth. Then also this sensitivity of the microphone is with respect to direction, but this it can be sensitive to let us say, for a 1000 hertz sound it could be omnidirectional, but may be for 10000 hertz sound it could be more sensitivity to sound coming from the front and less sensitivity to the sound which is coming from the back. Whenever we talk about directivity, we have to bear in mind two things that, of course the direction, but also at what frequency are we talking about.

So, whenever we are interested in measuring sound, let us say I am interested in measuring sound and I think that the frequency content of this sound coming from all sides is 10000 hertz, then I have to make sure that whatever microphone I pick should be able to capture all frequencies at least up to 10000 hertz from all the directions with same amount of sensitivity. Otherwise, my recording of sound will be wrong, my result, my input data will be wrong, so I will interpret that information incorrectly. So that is what I mean by directivity. Now, I will talk about different types of microphones which have different directivity characteristics. We will see some of these pictures.

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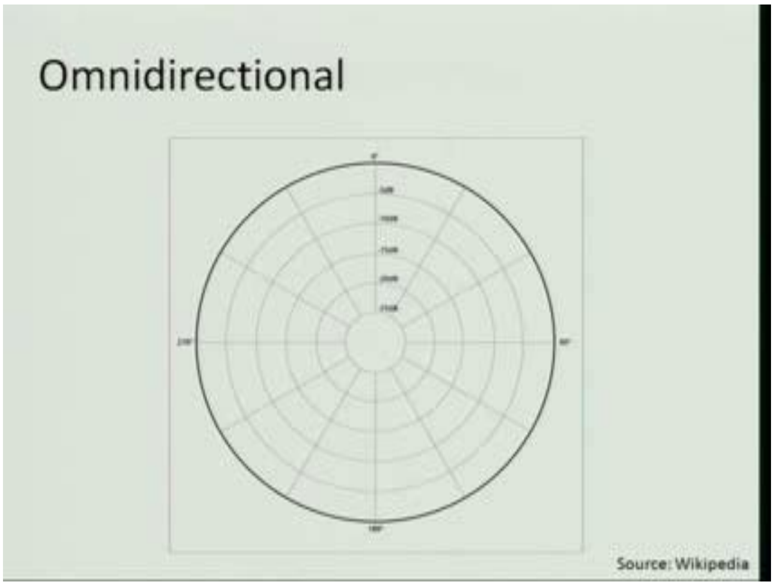

This is the omnidirectional microphone. Now on the picture what you was seeing is that you have this 0 degree direction, you have 90 degree direction in this cases oriented like this, in lot of cases you will take this as 0 but for some reason we have drawn it here there is nothing in particular about it. This is 270 degrees direction, this is 180 degree direction. This is my 0 degree line and I am going like this. And, what this picture shows is, that if I measure sound and this picture can change from one frequency to the other.

So, let us say this picture is well it for 10000 hertz. Then what it means is, that if I record the sound which is at 0 decibels. This dark line is 0 decibels. Let us say the original strength of the sound is 0 decibels, then this microphone will also measure 0 decibels in

0 degree direction, it will measure 0 decibels in 90 degree direction, 0 decibels in 180 and 0 decibels in 270. So, this means it is an omnidirectional microphone for 10000 hertz.

Maybe this sheet may not be perfectly circular, if I make the same pictures but for say 20000 hertz. You have to make these types of pictures for different specific frequencies and in which you are interested. But this is the picture of an omnidirectional microphone. This is the directivity plot for an omnidirectional microphone for a particular frequency, you can has several such plots for the same microphone corresponding to different frequencies.

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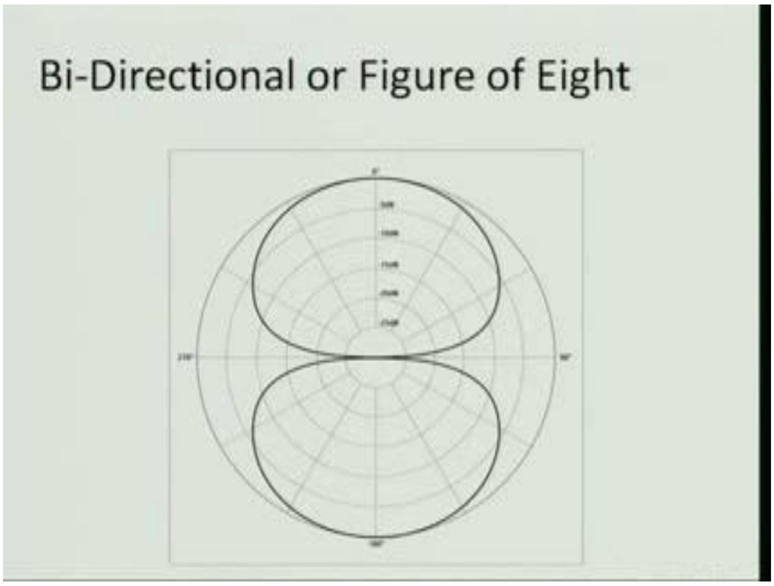

Now, let us look at this picture. So, this is a Bi-Directional microphone. What does it tell us? This is 0 degrees, 90 degrees, 180, 270, and let us assume that this curve is for let us say 1000 hertz. What does it tell us? Suppose, I have 0 degree 0 decibels sound or suppose, I have 100 decibels sound and that, 100 decibels is coming from 0 degree direction, then it will measure 100 minus 0 which is 100 decibels. This is 90 degrees, this is 30 degrees, this is 60 degrees.

Now, let us look at 60 degrees, this is a 60 degree direction. Now if I have a sound which is coming from 60 degree direction, so it is coming like this. Then this microphone and let us say the actual strength of the sound is 100 decibels, but then the microphone will measure, see this line light line is 5, this line is 10. So, maybe it will measure 6 decibels less. It will measure 94 decibels instead of 100 decibels. So, it is having more sensitivity in the 0 degree, less sensitivity in the 60 degree, some slightly less sensitivity in the 30 degree direction. Look at the 90 degrees direction, it measures almost nothing ok. So, it does not hear anything which is coming from 90 degrees angle. Same thing is true for 270. Then on the negative side, you have the same directionality figure. If a microphone has this type of a directional response, it looks like figure of 8, so this is known as Bi-Directional response or Figure of Eight response.

Once again, this plot may be specific to a particular frequency and if you change the frequency, may be make the frequencies higher or lower this can change significantly. So whenever we are talking about directivity, we are always talking about directivity in context of the frequencies or frequencies of interest. This is bi-directional.

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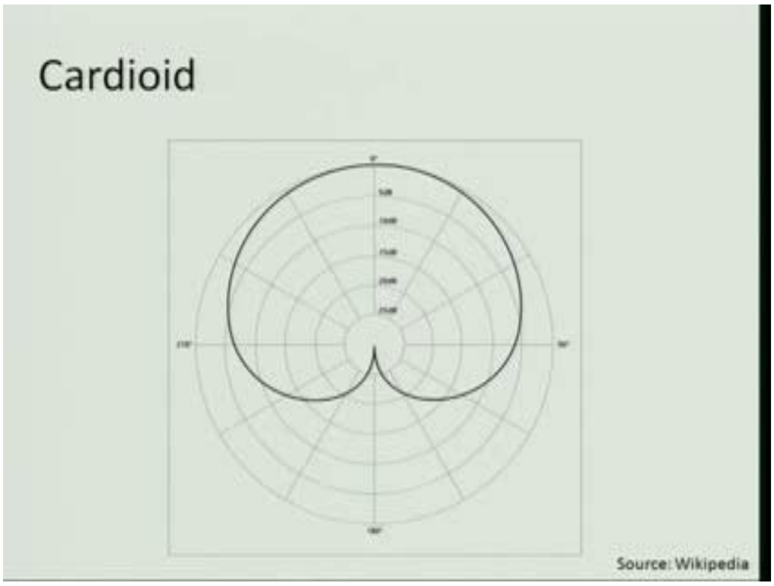

This is another shape and this directivity figure or directivity response is known as Cardioid response. What is Cardioid? See this cardiac arrest, cardiac problems, all these see cardiac it refers to this thing called heart. So, here the picture looks somewhat like a heart that is why it is on known as cardioid response, because the response of the microphone directivity response looks like that of a heart. And what you see in cardioid response is, that the microphone is more sensitivity to 0 degree direction so it can here very easily sound coming from the front, but if sound is coming from the back side, the response here is 0. It will be blind or it will be deaf to sound which is coming from the back side and from the sides it can still hear something, but it will here somewhat less or 5 to 7 decibels less at 90 degree and 270 degree directions. So that is my cardioid response microphone.

So, I can design mics with all these types of directivity characteristics and we have to make sure that we have the right type of microphone, or at least we know what type of microphone which we are using and which direction the sound is coming from so that I can use these curves to recalibrate and figure out what is the actual noise, which my instrument is measuring. The best type of microphone from measurement standpoint would be omnidirectional because then I do not have to do any calibration based on these type of figures. But again, I mean I have to make sure that, what is directional response of my microphone.

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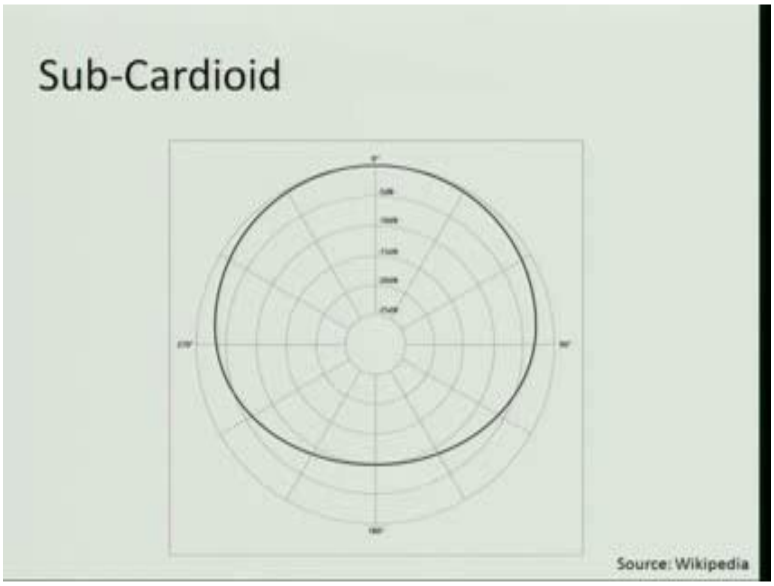

This is another response and their several such response, I will show 3-4 more then we move on. This is called Sub-Cardioid. So, this was cardioid, and this is sub-cardioid. It is somewhat falter in the lower half, so in this direction sound coming from the back side it hears its sensitivity 10 decibels less sound coming 0 degree direction. At 90 degree and 270 degree direction it hears may be 3 decibels less compared to 0 degree. These are classes. In this case, it is hearing 10 decibels less of sound which is coming from the back, but there could be another sub-cardioid mic which can be slightly better in the negative direction also. So, this is sub-cardioid.

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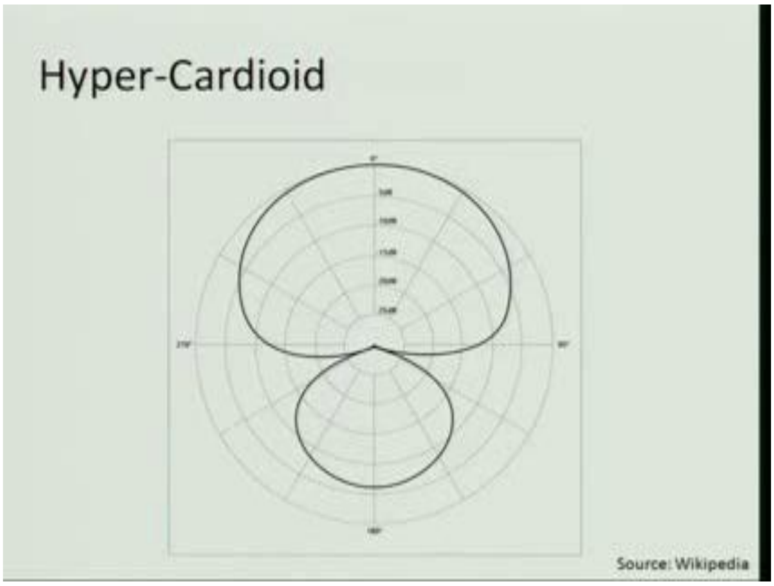

This is Hyper-Cardioid. What is Hyper-cardioid? This is again a figure of 8, but the one bulb of 8 is very small another bulb is very large, and that is what we known as hyper-cardioid. This is also directional, but the directivity is not as extreme as cardioid. In cardioid it was no sound, it cannot hear any sound coming from the back side, here it can hear something, but 10 decibels is less. This is hyper and then there is something even verse then hyper or better than hyper based on how you look at it.

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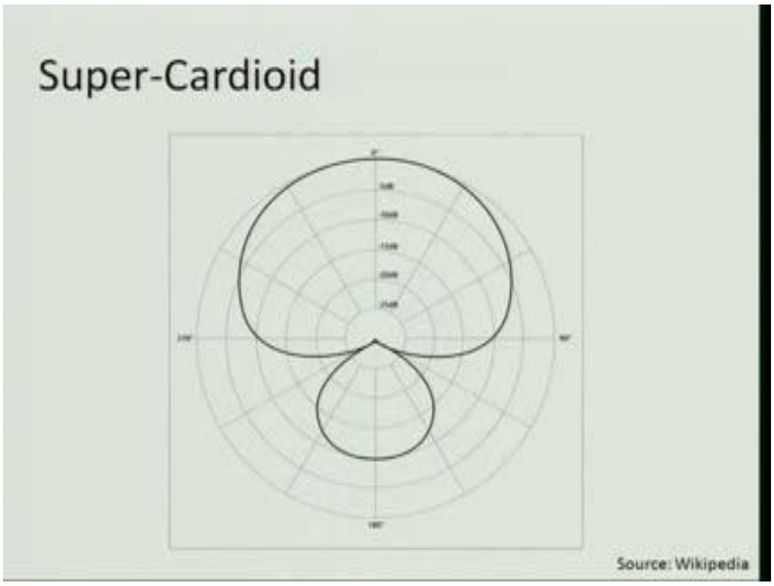

This is called Super-Cardioid. So, you have cardioid, sub-cardioid, hyper-cardioid, super-cardioid, all sorts of terminologies just for reference purposes you should know that.

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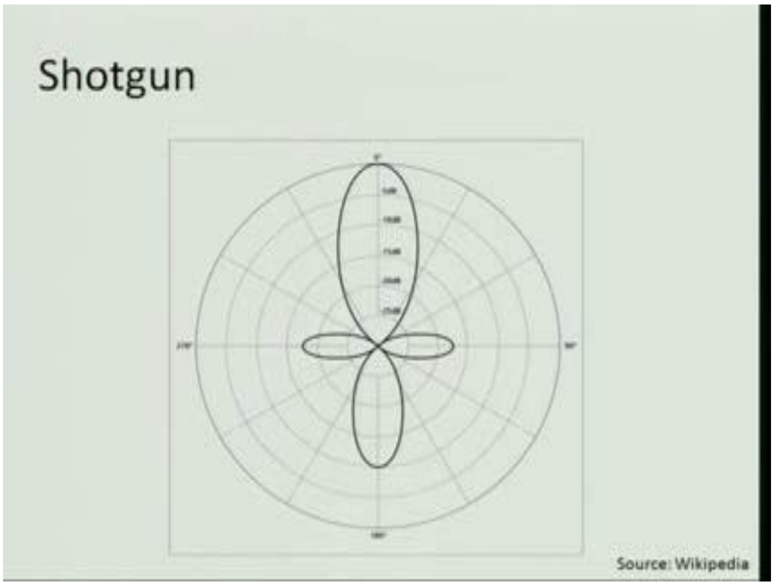

Then the last figure I am going to show you is that of a Shotgun mic. This likes a bullet. In lot of sensitivity in the 0 degree significant will be less on the back side and also in other sides you know at on the whole of back side. In these you are sensing something in the negative plane you know between 90 and 270 degrees, but in shotgun you do not hear a lot of noise if it is coming from the back plane of the systems. This whole is 0, this is whole thing is 0 this significantly less sound which you think is coming. So this is shotgun, this are very extremely directivity characteristics.

And people design these because suppose you are interested only in measuring sound from the front, and you do not actually want that what is the sound coming from the back side, there could be a situation like that. For instance, you want to know suppose you have a train which is coming from this direction and you are on a track you are not interested in sound coming from the back side, actually you do not want to measure it you may get confused you just want to see what kind of noise is coming from the front side, how fast the train is coming and all that stuff. Then you are interested in a very directional type of a measurement, you actually want to eliminate all the measurement which coming from the back side. So, all these types of microphones are available and it all depends on how we want to measure and what do we want to measure.

Now, what we will do is that I have introduced this notion of directivity. So, it is important that whenever you look at the microphone you always look at also its directivity characteristics and make sure that it meets your needs. Now, what we will do is, we will look at three different categories of microphones, and they all are related to this notion of directivity. So that is we are going to talk about. And before we talk, I may be I will spend another 3-4 minutes on something called Incidence.

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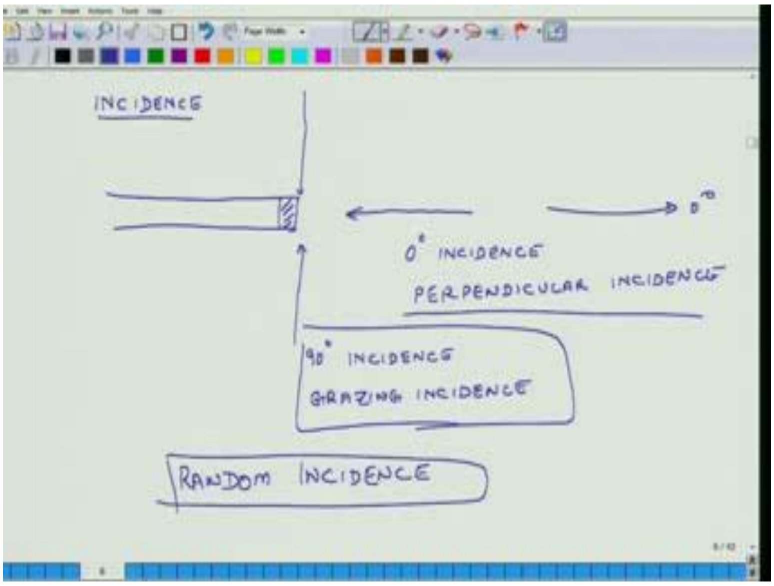

If I have a microphone, and if the sound is coming from this direction let us say from the 0 degree direction. Let us say this is 0 degrees, which is same as the axis of the mic then this is called 0 Incidence. It is also called Perpendicular Incidence. If sound comes from this direction or this direction that is like 90 degree incidence. And another term which is used quite often is known as Grazing Incidence.

Now what happens in a room, especially in a room where there are lots of reflections happening? So, when I talk some sound comes to directly in a room where there is a lot of reflection, but then you also have my sound going to that wall and then you get the reflection from this wall you also have all sorts of reflected sound coming to your ears from all directions. So, not only you are hearing direct sound, but you are also hearing a lot of reflected sound. And if the total amount of sound energy which you hear in a room, now I mention there could be two types of this energy which your ear will hear; one is this direct sound energy which is coming to your room to your ears, and the other is reflected sound energy. If the amount of reflected sound energy is much larger then this direct sound energy and if reflections are coming almost uniformly from all sides, then that is called Random Incidence. That is called Random Incidence.

We get some mics which are very good for 0 degree incidence. There are some mics which are very good for 90 degrees incidence. There are some mics which are very good for random incidence. Lot of these are omnidirectional microphones, they are good for random incidence applications. If you have a big auditorium and you are listening, sound is coming from all sorts of direction, and the direct sound which you actually hear from the speaker, who is on the stage that is very little, a most of the sound we are hearing is coming from all the sides. So, if you want to sense that kind of sound in that type of an auditorium, you may be interested in random incidence microphones. If you want to hear direct sound, then you have look at what kind of direction may be you are interested in 0 degree incidence microphone and things like that. Again, I wanted to introduce this concept, and now I will talk about three types of microphones which are available in industry from this standpoint of application.

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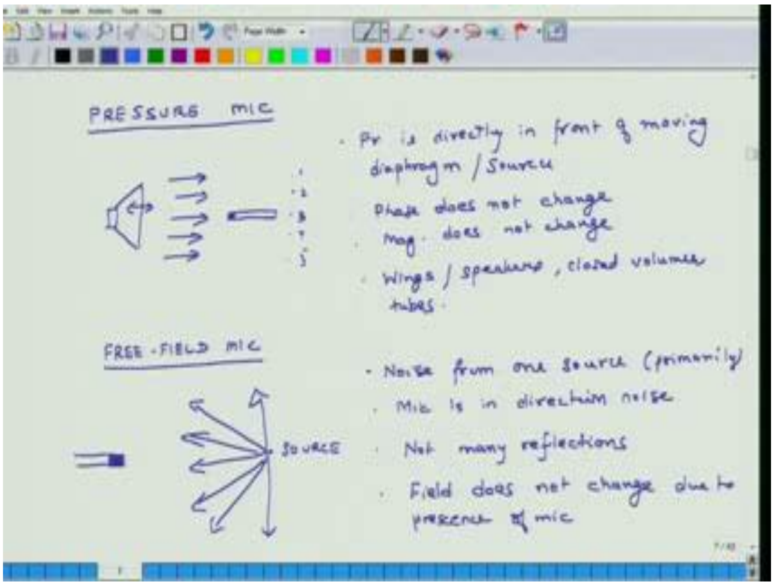

First is Pressure mic. So what do you have here, we have a speaker, and suppose I am very close to the speaker and this diaphragm is moving back and forth. The sound propagation field is something like 1 D. Then if I have a microphone here, then does not matter whether I have a microphone here or here or here or here or here the pressure will be same. This is the application for a pressure mic, where pressure is directly in front of moving diaphragm. An example could be a wing of an aircraft which is fluttering like this and you want to pull put a microphone here, so it is same kind of physician does not have to be speaker all the time, so diaphragm or source.

Second, when you are near the source and if you move along the length of the source phase does not change. Also, see if I move from between these 1, 2, 3, 4, 5, all these points phase does not change and magnitude also does not change. So, where would we use these types of microphones, near wings, speakers? We have to be near the speakers, if you are far from the wing then it will be different, close volumes tubes and so on and so forth. So that is what pressure mic is.

Then the second category is Free-Field mic. This is the second categories. Here, I can have a microphone, this is my microphone, and the source may be here so it is like this. You have usually a single source and the area in which you are measuring this noise is free field, what does that mean? That you go out in the field. There not a lot of reflection happening so its free, you are in the field and no reflection happening, so noise is free to travel in all sorts of directions you know without getting reflected.

Noise from one source primarily, because there will be never a situation where you will have only one noise source, more or less I mean if you have very one dominant noise source and then mic is in direction of noise, and then not many reflections. The other thing is that the field does not change, you know field does not change sorry excuse me, due to presence of mic and we will talk about it. What does this mean? We understand noise has to be from one source, microphone is there and it is in the direction of the noise not many reflections. The last point is that field should not change due to the presence of mic. One property of sound is that if its wavelength is comparable to the size of an object, then the sound pattern changes you know the pressure field, the variation of pressure with respect to x y z it changes. This too for all waves not only sound waves but all waves.

If I have a 1000 hertz wave, its wavelength will be 340 meters as per second divided by 1000 so it will be 34 centimeters. And if I have an object, let us say 5 millimeters in diameter, in this noise field, then 5 millimeters is extremely small compared to 34 centimeters which is the wavelength of the sound at 1 kilo hertz. In that case, this 5 millimeters object will not change the sound field you know the pressure gradient of the field, because sound is nothing but pressure wave. Pressure gradient does not get altered significantly because of the presence of this object as long as this object is very small compared to the wavelength.

Now suppose, I have may be 30 centimeters diameter ball, you may be have a football or something and that I place in this pressure field. Now, wavelength is 34 centimeters, ball is 30 centimeters in diameter, they are comparable. In this case, the pressure field will change. If the pressure field changes, then our intent of making the measurement is destroyed, because we are not measuring the actual pressure which would have been there in absence of this instrument. So, what this means is, that you have my microphone size should be significantly smaller then the wavelength of the sound which I am interested in measuring. That is the implication of this field should not change due to the presence of the microphone.

If I have all these things, then I can use a free fields microphone to make the measurement and in lot of cases I do this measurements either I am out in the field on, or I can also do these measurement in anechoic chambers and these chambers are especially designed rooms where you have no reflections or sounds. So, if there is no reflection of sound it is same as free field condition. Because in free field, we assume that there are no reflections. To artificially create those conditions in lab we design anechoic chambers. So, that is the other case. We have a pressure mic then we have free-field mic

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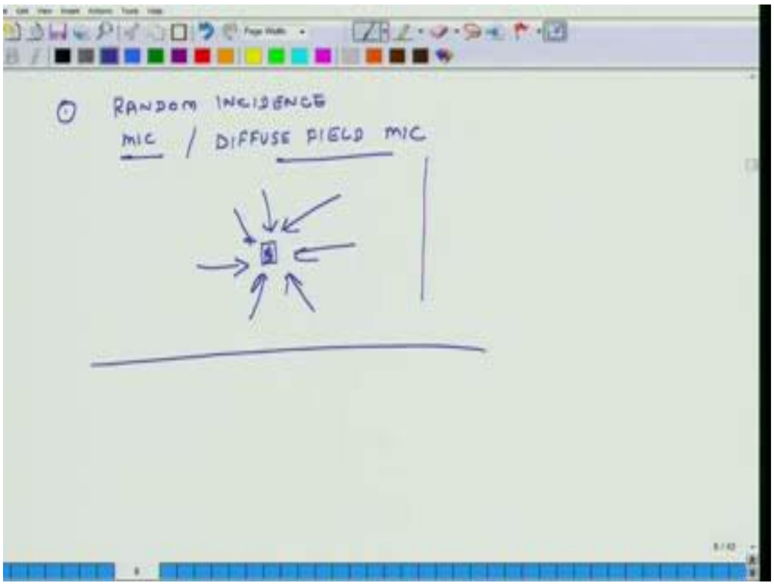

The third category of mic is Random Incidence mic. In this case, you have a microphone and sound is coming from all directions, and I am interested in measuring sound coming from on all directions. So in that case, I use this random incidence mic, its directivity characteristics have to be more or less omnidirectional because otherwise, I will not be able to capture sound with same sensitivity which is coming from all the directions. So, this is also known as Diffuse Field mic.

So, these are the three categories of mics, which we have discussed from the standpoint of type of sound which we have measuring, pressure field mic, this free field mic and random incidence mics. This closes our third lecture, and we will continue this discussion tomorrow.

Thank you very much. Bye.