Audio System Engineering
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Lecture – 13
The Acoustic Environment

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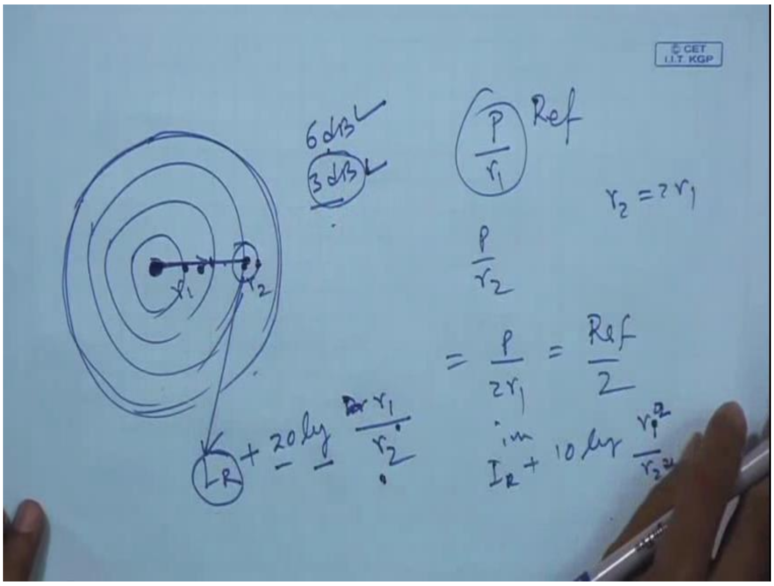

So that up to this point, we have covered that sound transmission, sound refraction and then sound wave propagation that basic theory part. Now, we go for that application oriented for now right now. So, now we go for the acoustic environment. What happen if you switch on a let us I switch on a sound source here, if I switch on this let this is the sound source. If I switch on the sound source, sound wave will be generated and it transmitted in a spherical nature, spherical wave transmission will be happen. So, let us I put on a microphone in a open field, what will happen the loudspeaker in open field, so sound field will be generated and will be travel along the field. So, it create an acoustic environment may be there is no one single loudspeaker, so I play a loudspeaker somebody moving by a curve, somebody walking and somebody making a noise, so all kinds of sound source contribute to the acoustic environment. So, it creates an acoustic environment.

Now, if I create a sound here as per the inverse square law rule that every doubling the distance from the source, the sound intensity will be dropped by 6 dB, and sound pressure level will be dropped by 3 dB, because 1 by R square in case of intensity, pressure 1 by R. So, once I double the distance, the half power time 3 dB will be down, so that means, in case of sound acoustics, when a acoustics propagate in a environment, it supports the inverse square law. So, I can sound factors, which effect the acoustic environment, which I do not know, which are factor which effect this acoustic environment. The factors are inverse square law; that means, if I produce sound, if I away from the sound, once I away from the going away from the sound source, every time I double the distance, my intensity will be dropped by 6 dB, and power will be, level – sound pressure level will be dropped by 3 dB.

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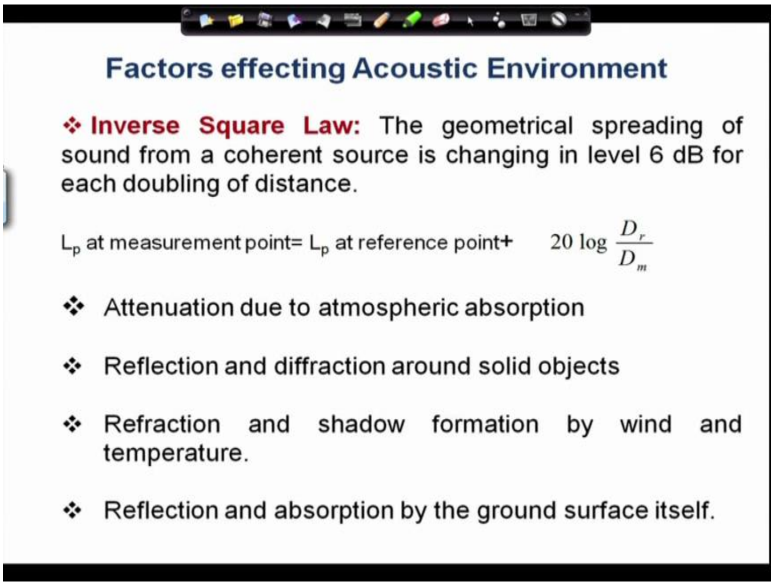

How it is done you know, if it is power is P at r 1 let us at r 1 - this point, the power is P, so it is the sound pressure is P by r 1. Now, once I got it up r 2, then it is P by r 2. If r 2 is equal to 2 r 1, then it is nothing but a P by 2 r 1, so it is nothing but a pressure level is half of the reference point. So, if I say it is a reference point, then it is nothing but a reference point pressure level divided by 2. If I converted it to dB that means, that if the reference point pressure level is lets L R then plus twenty log reference point distance D r or you can say r 1 divided by r 2 point distance r 2. So, the power level at r 2 is nothing but a reference point sound pressure level plus 20 log reference point measure distance divided by the measurement. So, it is the measurement point distance.

For intensity, it will be same I R plus - I R in dB plus 10 log similarly r 1 square divided by r 2 square or you can say that square will be removed, so it is nothing but a r 1 by r 2. So, r 1 by r 2, understand. So, in case of, doubling the distance intensity 6 dB and pressure level 3 dB so that is called inverse square law.

Then if I produce a sound in an open field, I observe then up to certain distance I cannot heard the sound. It may be effect of the inverse square law. It may be effect of the attenuation due to the atmospheric absorption. So, if the atmosphere, there is air, so through the air, sound is travelling. So, there is atmospheric absorption is happen. So, due to the atmospheric absorption also sound will attenuated.

Then there is a reflection and diffraction around the solid object. I create a sound, there may be a wall, there may be a inclined plane, there may be a sliding ground, so from everywhere the sound will be reflected and refracted that will create a problem that will create that effect the sound acoustic environment. Then refraction and shadow formation by wind and temperature; there is a shadow formation by wind and temperature, we will discuss it detail. And then reflection and absorb by the ground surface; ground surface also reflect some energy and absorb some energy. So, all kind of obstacle is contributing the acoustic environment. Let us we discuss one by one.

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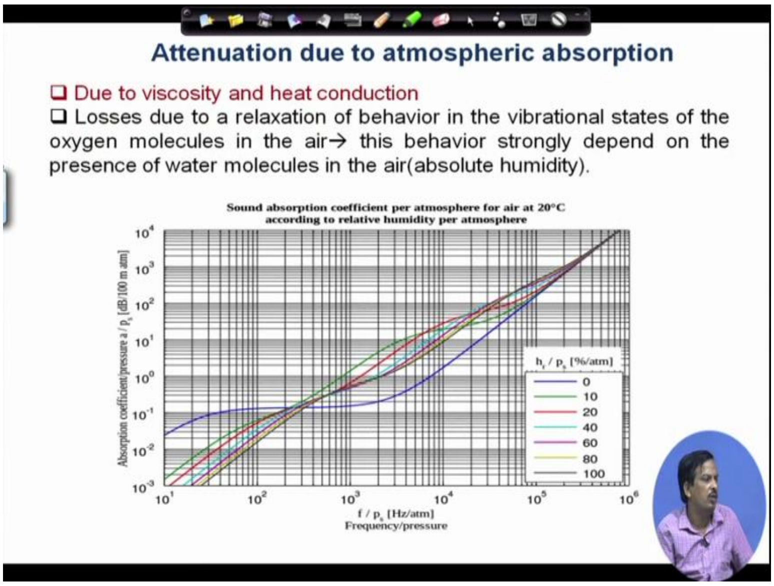

One is called attenuation due to so inverse square law you understand. Now, attenuation due to atmospheric absorption, it is done due to the viscosity and heat conduction of the air medium. When the sound is travel, then due to the viscosity of the air and heat conduction of the air, we are assume that medium is adiabatic, but there may be heat conduction happen that create a loss. So, there is a lot great deal of research on that and they find out that it is absorb, sound absorptivity will be increased, if there is viscosity and heat conduction is increased.

Then loss due to the relaxation behavior of vibrational state of the oxygen molecules in the air, which also depends on the humidity – absolute humidity, sound absorption - atmospheric absorption due to the atmospheric humidity also depend. So, if you see this following curve is output of some research that how that humidity effect the sound absorption. So, this is curve is given. So, I can say the atmosphere is nothing but observer.

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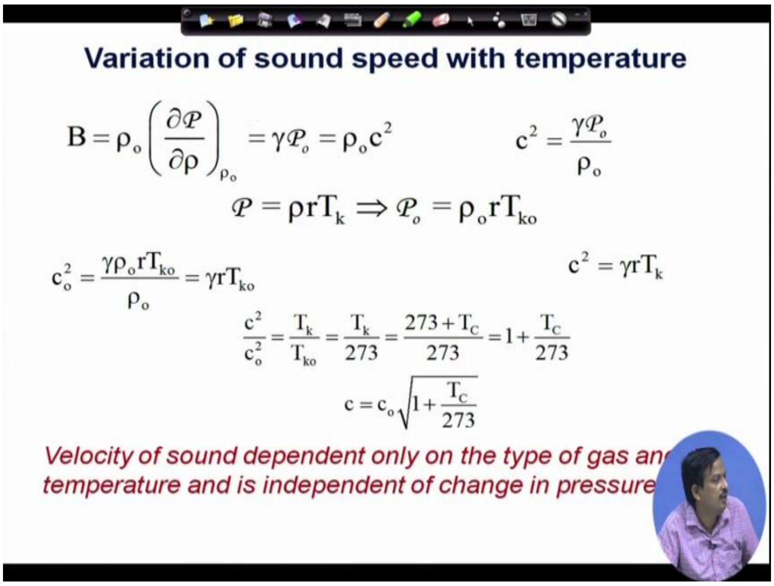

Next, very important part that we said the velocity of sound depends only on the type of gas and the temperature and is independent of change in pressure. What is the meaning is there that if a acoustic environment, the velocity of the sound depend on the type of gas and temperature of that medium not the pressure. That means if the velocity of the sound in Calcutta and if I measure the same velocity of the sound in Darjeeling which is higher high altitude the sound the atmospheric pressure level is less, equilibrium pressure level is less that sound speed will be same if the temperature and type of the air is same. So, in that two cases sound speed will be same. So, this is the proof how the sound velocity of the sound only depends on temperature if you see, velocity of the sound is only depends on temperature. So, if the temperature increases, the velocity of the sound is also increases, if you can see again very small deduction of already discussed in that previous class.

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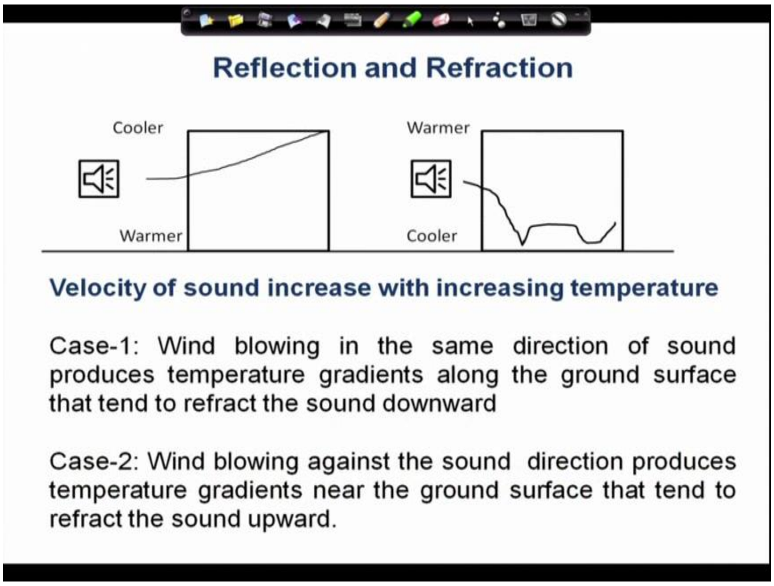

Next, if that is happen, then there is a shadow formation due to the temperature variation. See these two pictures. One picture is that that let us would not discuss about the case one and case two, let us first physical discuss on. Suppose I create sound in here, and sound is travelling along this direction now I said that there is a there is warmer that this portion air is warmed and this upper portion air is cooler let that kind of gradient is temperature gradient is happened.

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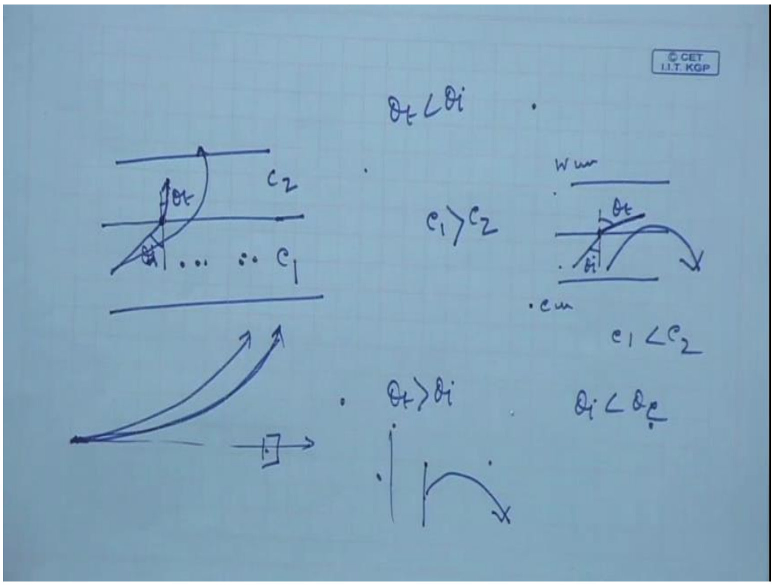

So, I can say that this along the ground it is warmer, and above the ground it is cooler. Now, once let this is the one boundary, once the sound is incident on this boundary with a angle of theta i – incident angle, now I said that if the temperature is high, velocity of the sound is high. So, if it is velocity of the sound id C 1 and velocity of the sound is C 2, since C 1 is greater than C 2 then I said the refracted wave will be towards the normal. So, this is theta t, theta t is less than theta i, we have already proved that. So, in that case, the sound will be bending towards the normal. So, what will happen the sound path will be looks like this, when upward? So, sound is wanted to go this straight line, but due to the temperature gradient it creates a path like this way. So, if the person is standing in here, he cannot heard that sound, because that sound that sound is not coming this direction, sound is already go upward. So, there is shadow formation is happened.

Similarly, if upper portion is warmer and lower portion cooler, what will happen, let us this is the boundary, sound is incident on that boundary, so this is the incident angle theta i. Now, C 1 is less than C 2, so if C 1 is less than C 2, and theta i is less than the critical angle, then what will happen, sound will be away from the normal, theta t is away from theta t is greater than theta i, so it is away from the normal. So, it is away from the normal that means, the sound will be bends downward. If that that kind of lower portion is cooler, upper portion is warmer then what will happen, sound will bend downward. Now, you think about the phenomena, sometime you say there is a loudspeaker is playing and that is wind on that direction of the sound we said that since the wind is in direction of the sound that is why the sound travelling long distance. Actually, that mean does not affect the sound velocity, sound velocity; sound is affected due to the temperature gradient for the wind waving there.

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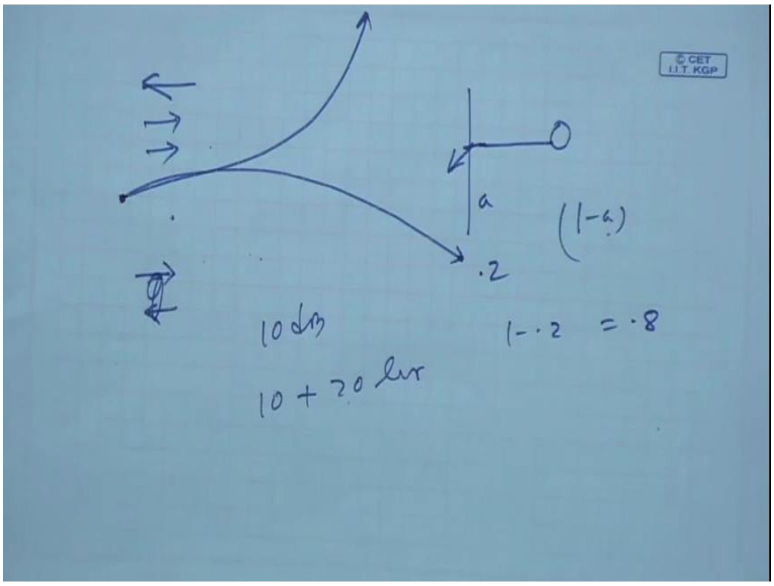

So, in the case of case one, wind is blowing in the same direction of the sound produces temperature gradients along the ground surface that tend to refract the sound downward. So, if a person, if a sound is coming from here, then it is going downward, for same direction the direction of the wind is same as the direction of the sound. Now, if the direction of the wind is different from the – opposite direction of the, direction of the wind is this and sound direction is like this or lets the wind is blowing this direction, then what will be happen, the sound will be refracted upward, because of the temperature gradient. So, that is why sound cannot travel long distance, where it is going upward. So, this refraction and reflection effect will be.

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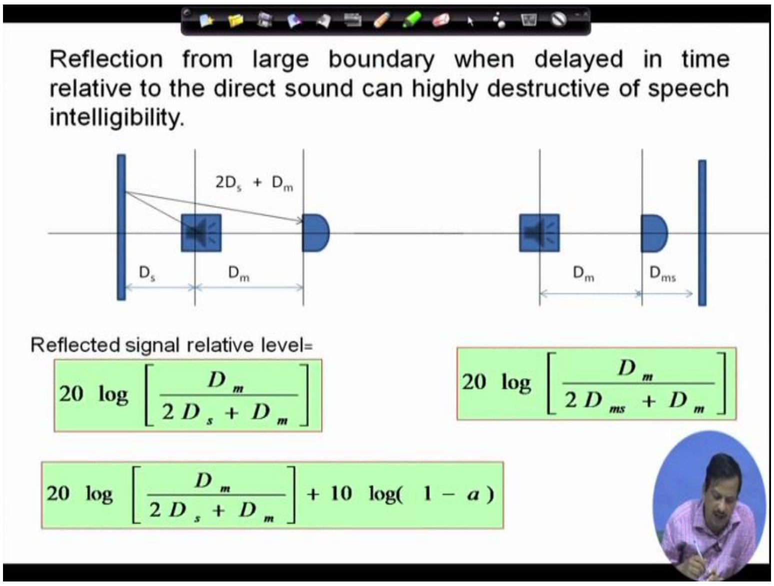

Then what is the reflection effect, let us acoustic environment, I create a some sound in this room, so this sound will be let us only the counter wall is there, so the from the front wall, it will be reflected back. Let us see this picture. I create a sound here, and there is a reflector. Now, distance between the source and measurement point is nothing but a D m; and distance between the sources of that obstacle is D s. Then refracted, sound reflection path is going from here, go to D s, and reflected back from D s. So, let us normal we see them, so distance is distance is reflected, reflected distance is 2 D s plus D m. Similarly, if it is arrange like this way, then it is nothing but a reflected this is the direct sound and reflection is going that that and going by that, so it is nothing but a 2 D m s plus D m, reflected sound path.

Now, you know that what should be the reflected power, reflected sound pressure level. Measurement point you know where D m so it is direct sound power divided by the distance plus direct from. So, if the direct sound I measure at the measurement point 10 dB, so it will be 10 plus 20 log D m by 2 D s plus that. Now, if I say I produce 10 dB, but once it is reflected from the wall, wall absorb some parts, so the absorption coefficient is a. So, 1 minus a is reflected. If the absorption coefficient is a, let us two percent is absorbed; that means, it 92 percent will be reflected. Or let us reflection coefficient is 0.2 then 1 minus 0.2, so 0.8 percent of the energy is reflected. So, 10 log 1 minus a will be the actual sound pressure level of the reflected sound. So, that way we can measure.

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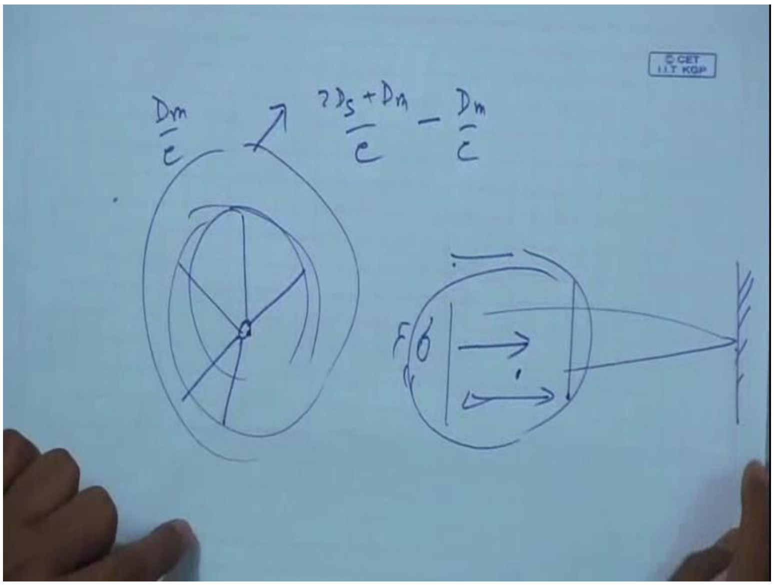

Then what is the time, there is another thing, what is the direct sound time is nothing but a D m by C, in case of first case. Reflected sounds are nothing but a 2 D s plus D m divided by C. So, what is the time difference between the reflected sound and direct sound minus D m by C, I can say or it is 2 D s by nothing but a 2 D s by C, so that is time, time we will discuss. What is the effect of the time delay for rooms enclose all these things will be discussed. So, this is the reflected sound delay.

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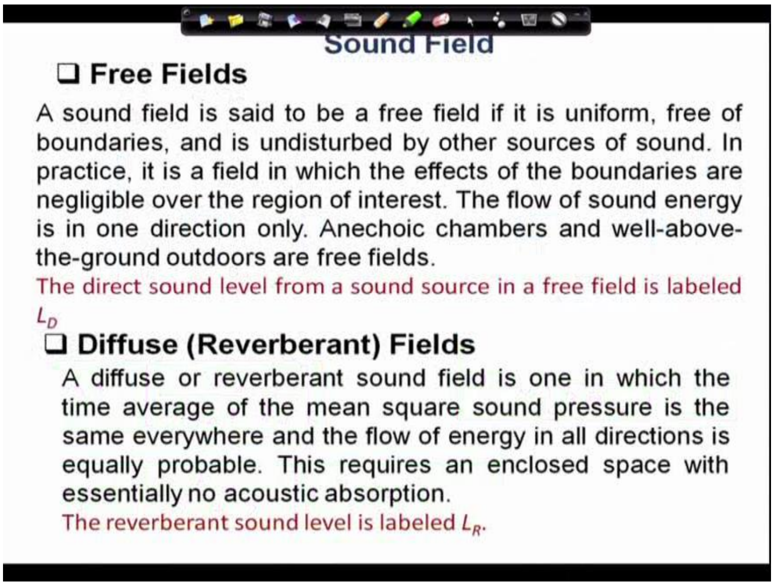

Now, there will be the another thing, once a acoustic environment, when I talk about acoustic environment I said that if I produce a sound in an environment it create an acoustic environment and some parameter like atmospheric absorption reflection, refraction, temperature gradient all ground surface, all create a some effect on that atmospheric environment acoustic environment. Ambient noise also creates an acoustic environment.

Now, if I say that I produce a sound in here; that means, it creates a sound field you know that. If I pass electric signal on a cable, it creates electric field. Similarly, if I produce a sound here, it creates a sound field. So, this whole environment is called sound field. Now, that sound field has different kinds of variations. First one is called free field. What is free field, free field means that sound only travel, there is no reflection that from any surface. So, this is called free field. So, a sound field is said to be a field, if it is uniform free of boundary and is undisturbed by other sources of sound. In practice, it is a field in which the effects of the boundaries are negligible over the region of interest. So, that means, if I say I create sound here and after a long distance, there is a wall; sorry so that wall may not there is a reflection, but reflection energy in here is very small. So, I can say up to here and here is a free field, because there is no reflection kind of things, there is no extra sound source also. So, only the source sound is propagated based on the inverse square law principle; that means, travelling the distance, 6 dB down intensity.

So, in that case, I can say it is free field. Example, real life example, anechoic chamber, if you visited any microwave lab, there may be anechoic chamber; that means, there is no reflection of microwave frequency. Similarly, I can make anechoic chamber of the sound; that means, I can make a chamber, where no reflection from anywhere; that means, there is no reflection sound. So, only one directional source sound is there, so that is that room sound is called free field.

Now, there is another field is called diffuse field or reverberant field. A diffuse or reverberant sound field is one in which the time average of the mean square sound pressure is the same everywhere and the flow of energy in all directions is equally probable that is the definition. In practical, what is it.

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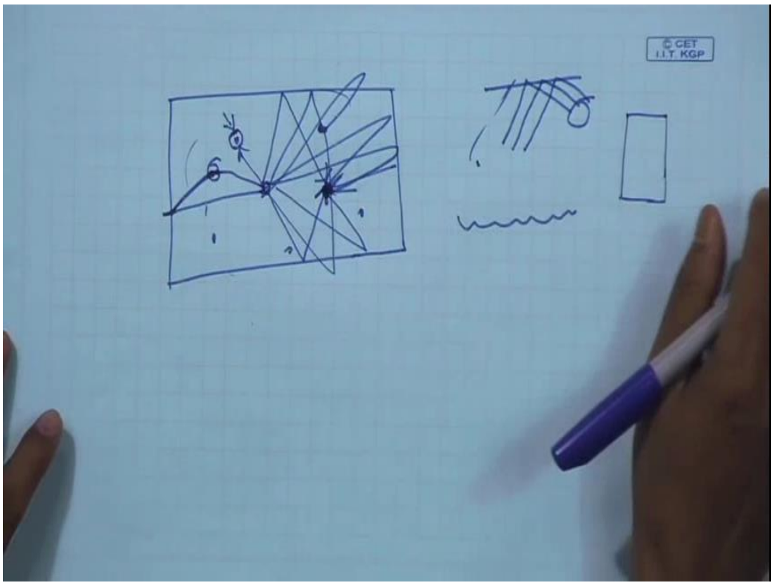

Suppose, I create an enclosure and this enclosure all six walls, all six planes are made of a completely reflective surface. There is no absorption, so that means, if I produce a sound, sound will be reflected back, sound will be reflected back, sound will be reflected back, sound will be reflected back, so all from all points sound will be reflected back. In that case, if in a reverberant sound field, in which the time average of the mean square sound pressure in the same everywhere; that means, if I take the mean square sound pressure level this point, and take the sound pressure level is this point. It will be reflected on different path and this point, this point, and this point, this point all point measurement will be same. That means in all directions equal reflection is happened, and total number of reflection produce reflection produce reflected signal creating that energy and direct sound total energy will be same in every point of the room.

Because if it is direct sound, it is reflected, since the reflection path is less then direct sound may be less, but since the reflection sound will be high so it is compensate. So, in that case, I can say if it is a completely reflective enclosure room and if it is create a sound, and in every point of that room, the RMS sound pressure level is same then you said this sound field is nothing but a diffuse or reverberant sound field.

Now, you know that reflection is two types. What diffuse, what you mean by diffuse? If it is a regular reflection then what will happen the sound source will be direction on it makes sound source direction on. That means, only this wave will there will be no reflection on that, scatter reflection will be not there, so that is why I want a irregular reflection so that everywhere the number of reflection sound mean or average number of reflection sound will be same. We will discuss later on also this one, so that is why it is called diffuse field or reflective field.

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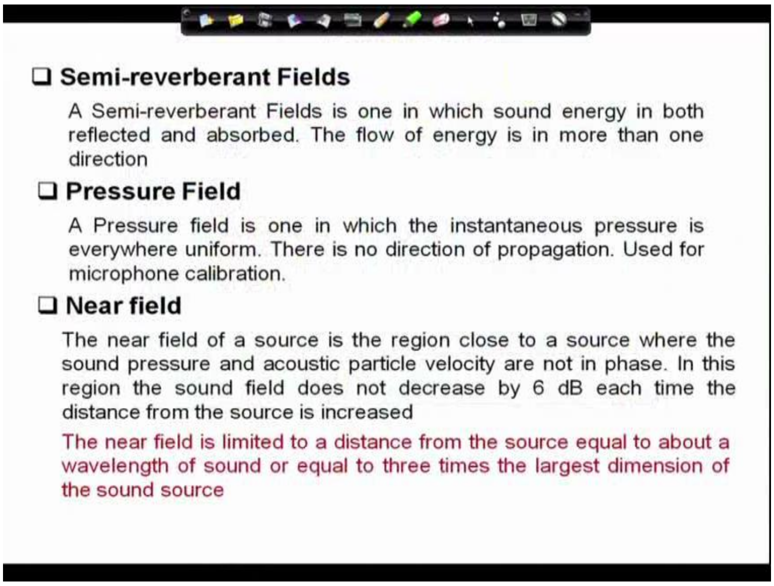

Then there is called semi-reverberant field. Can you give example of a reflective field, reverberant sound field, and real life example? When you entered in a bathroom, all the walls are crystal and ceiling also not that high, if you sung, if you create any sound on the bathroom, it create an reflection at create a sound field, it is almost diffuser reverberant sound field. Now, I go for another sound field, which is called semi-reverberant sound field.

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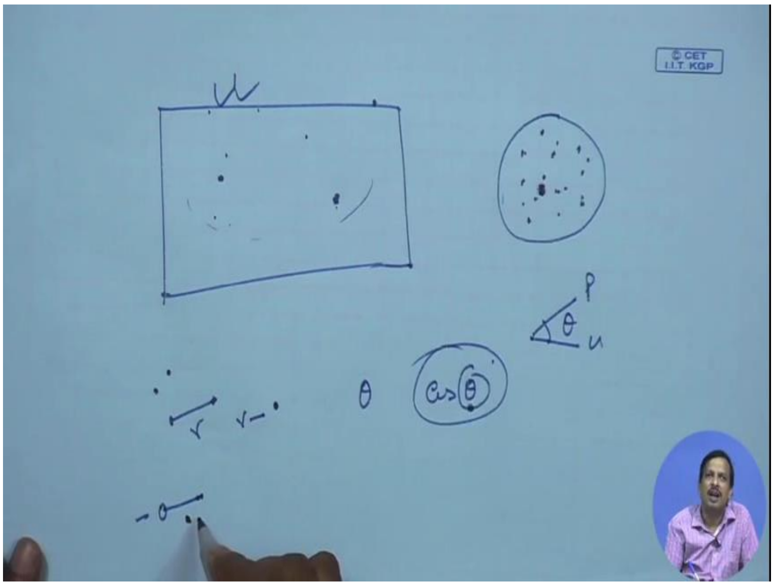

What is semi-reverberant sound field, the semi-reverberant sound field is that where only one parameter I relax that all the wall, all the surface which is have there, there is some portion of the sound is absorbed by the surface that is not completely reflective surface, some absorption is there. Then it is called semi-reverberant sound field. So, in case of semi-reverberant sound field may not be all point the power energy will be the same. And in another flow of energy is more than one direction.

Now, there is another sound field is called pressure field. A pressure field is the one in which the instantaneous pressure is everywhere uniform. If a sound field is like that that instantaneous pressure in sound pressure in everywhere is same, they may called the pressure sound field. This is used for microphone calibration, microphone calibration we use this kind of uniform pressure sound field.

Then there is a depending on the position of the field, there are two types; one is called near field, another is called far field. What is near field? If you remember when I discuss about the spherical wave propagation I said that if the frequency of the sound or if the distance from the source r is comparable with the wave number wavelength of the sound, wavelength then the theta cos theta. Have you remember the cos theta, theta is the angle between the pressure and particle velocity p and u that angle theta will be large. So, in that region when the theta is large in that region, it does not follow the inverse square law.

So, the region, from the source to the region where the sound energy or sound propagation does not follow the inverse square law or the region which is that the distance from the source is so small compare to wavelength, the theta is high, the angle between the pressure and reflected particle velocity is high in that region inverse square law does not support that region is called near field. So, it is near to the source that is why it is called near field.

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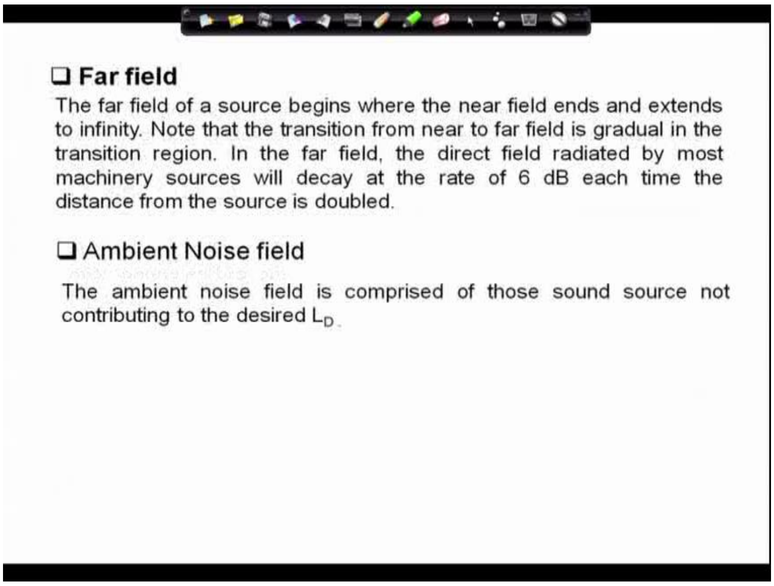

So, what is far field? Far filed is that where the near field is end, the far field is start and goes up to infinite, so that is called far field.

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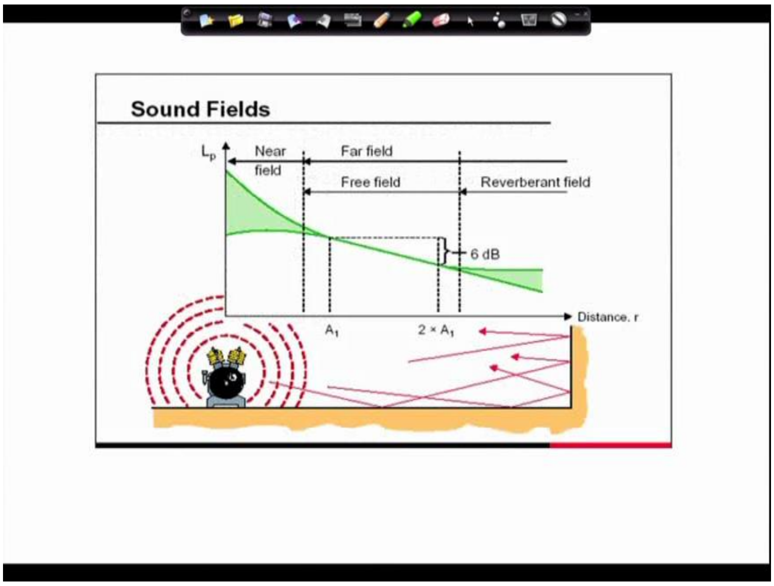

Now, I just gave one picture. If you see, let us this is the sound source, I taken from internet that so up to here, if you see the near field let up to here it does not follow the inverse square law then I called this is the near field. This portion is the near field. And far field is the end of the near field to the infinity is the far field. Now, if you see interesting observation, that I said the wall is here, so there is a reflection, but in here this region there is a reflection region very low, so I can say the only the direct sound existing here, so this is called free field region, only direct sound.

And this end left here, up to here, there is no reflection, sound is not there. Once the reflection sound start, we call reverberant field. So, three field, near the speaker – near field; after the near field, far field is started; in far field two types of field one is called free field, another is called reverberant field. So, I can explain, I can discuss that how the depending on the placement of the speaker, I can calculate which is near field, which is far field and which is reverberant field. This will be used when you design the auditorium.

Now, there is another point is called ambient noise field. Suppose, I produce I giving lectures and there is ac; and it creates a constant noise. So, it is an ambient noise. Or suppose there is a consort is let us in open air, open air let us say in our OAT – open air theatre, and beside that there is a road, so when the car is going on the road, it creates on the noise. So, it is ambient noise, noise is created that is called ambient noise. So, ambient noise is also affecting the sound field.

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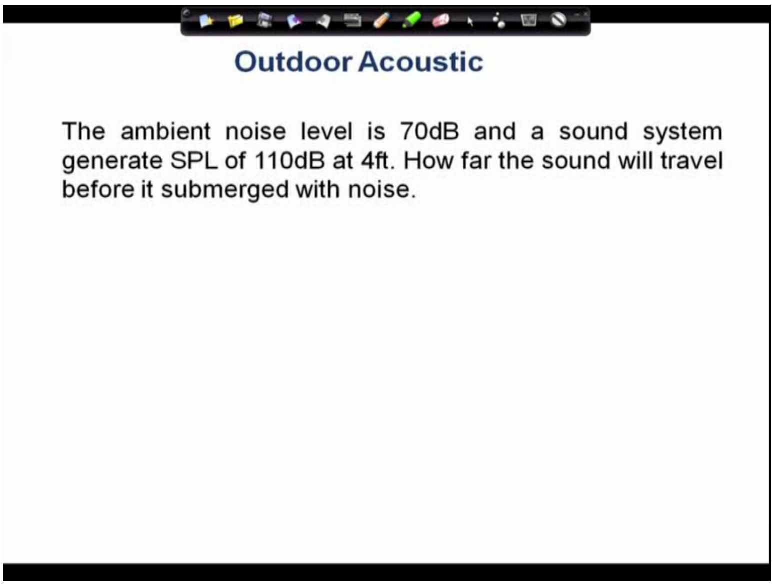

For example, suppose, I told you that let us I create the ambient noise level in a field, lets I want to (Refer Time: 27:22) and construct in our (Refer Time: 27:28). So, what is that I have put that some loudspeaker and I said that the when the loudspeaker is not on, the average ambient noise is 70 dB.

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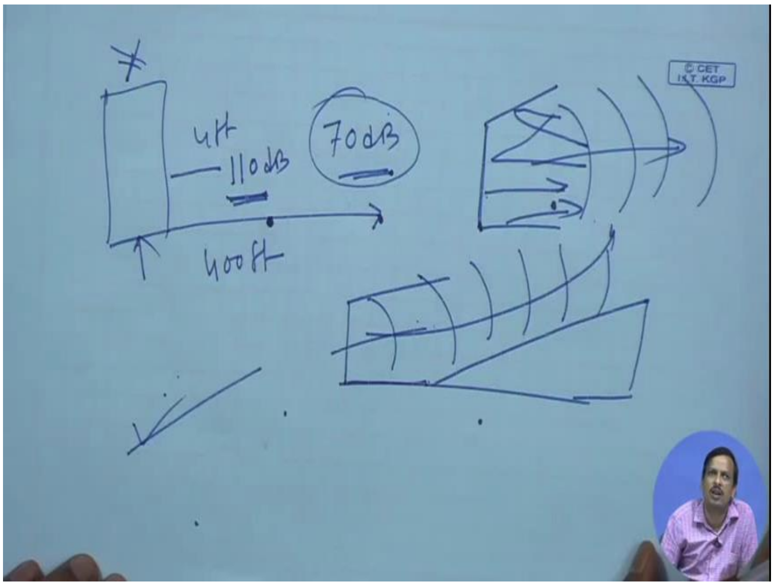

Now, I switch on the loudspeaker, and after 4 feet, I measure that it is produce 110 dB sound. Then can I calculate how far the sound will be travel before it is somewhat with noise; that means, in up to which distance audience can heard the sound, I can calculate. Because I said that just forgot about the ambient absorption by the atmosphere and absorption by the people, who are standing there and the noise created by them and that also create the ambient noise.

Lets people standing on there and they are create a noise, when the loudspeaker is not on is 70 dB. Now, let us atmospheric absorption is not there, room is not, wind blowing is create some help or distract, so this creates an effect, but lets it is not there. Then what will happen, after 4 feet if it is 110 dB, then it is ambient noise is 70 dB, then I can easily calculate how far the sound will be travelled. So, it will be around 400 feet, the 400 feet the sound will be travelled. So, I can calculate how far the sound will be travel and then after that distance I put an another speaker, so that sound can travel long distance, so it helps me to calculate where I put a loudspeaker in that region.

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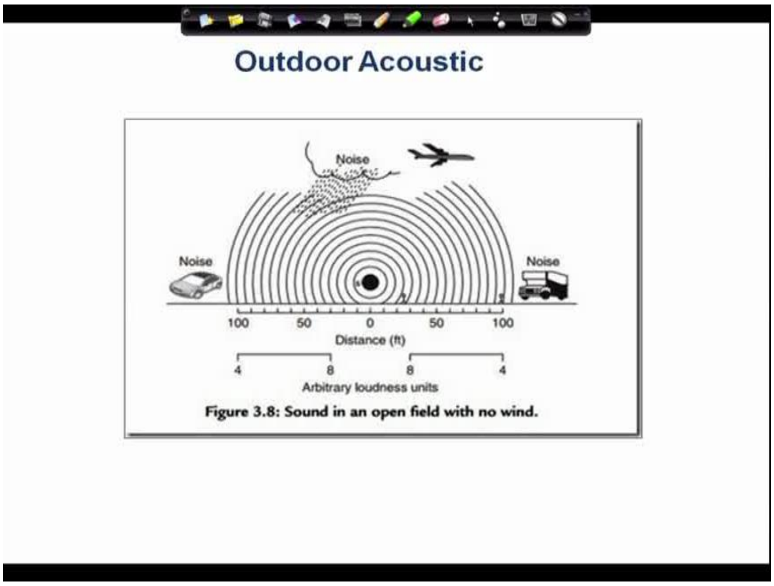

Now, if you see the picture, this is the sound source, it creates a field and different kinds of noise are there; now, in acoustic open air or outdoor acoustic, we found there is stage; this kind of stage is there. Once I put a stage, this kind of stage, the sound is directed. So, in this direction, sound will be enhanced, because this direction sound will be reflected back in this region.

Similarly, if I see that instead of if I make the stage like this, and put the audience in a ramp then what will happen, the sound will be again enhanced. Or air if it is, sound is going upward also, and this can help to travel the sound in long distance. So, this kind of outdoor acoustic arrangement we make. If you go to the open air theatre – OAT, you see the seats are rammed, it is not only for viewing, and it is also for sound that every people can saw, heard it clearly. We will thoroughly discuss when we design the auditorium. So, this is called acoustics environment.

Thank you.