Principles and Applications of Building Science
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Lecture – 17
Acoustic Design Considerations

In this module we will be looking at the acoustic design consideration. So, far we have been looking at certain indices, now specific numbers which are useful. Now we will get a slightly bigger perceptive say if you are designing an auditorium, or if you are designing a lecture hall what are the steps you know how do you follow, which are the crucial things I am not going to do a step by step, hand holding of how do you design an auditorium, but I will be talking about few important things which come across when you design a listening space.

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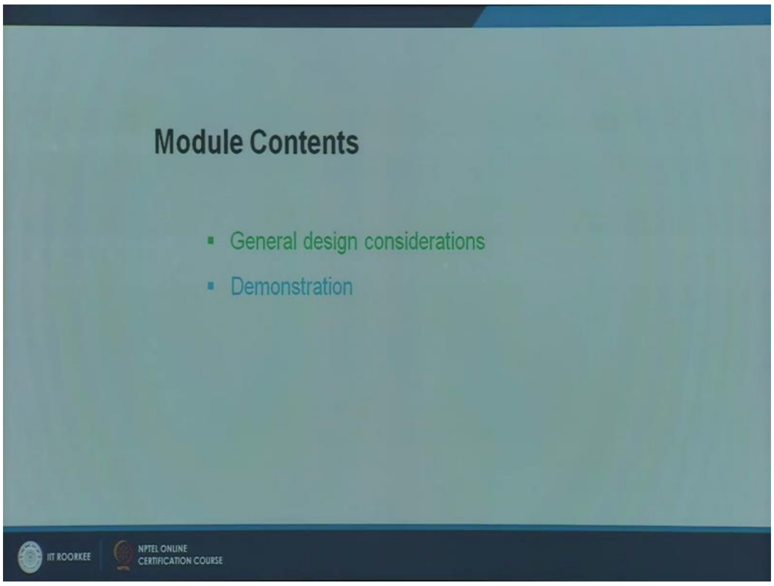

So, we will look at general design consideration, apart from this in this module I will be demonstrating one of the auditorium project, using a software called Odeon; Odeon acoustics ,which is a very you know detailed and interesting software. One of the most sophisticated you know tool available today. I will be demonstrating one of the auditorium projects using that particular tool.

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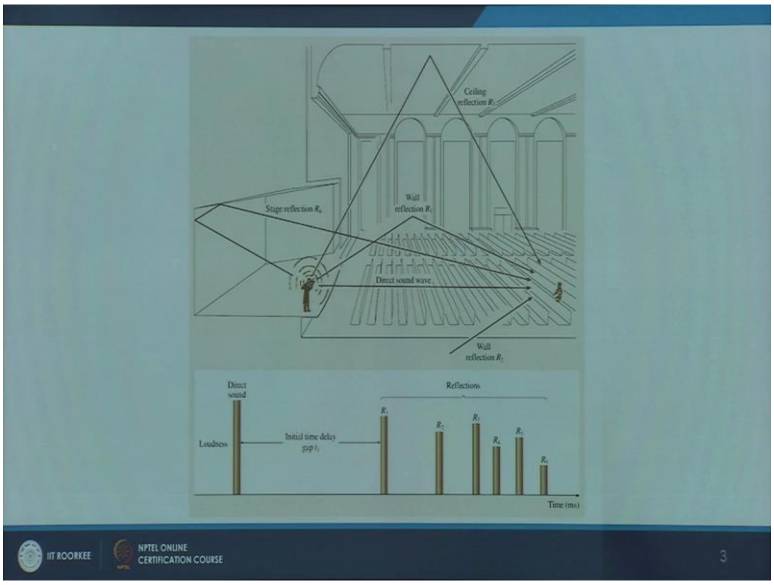

So, we were talking about sound transmission. So, you have an auditorium stage area, and the listener here, you have direct sound wave. This is what I was trying to tell you last module. So, you have a initial time delay gap which is called I T D, or initial time delay gap, if you are closer you listen it in a say you know, say 1 millisecond 2 millisecond or 5 millisecond, you get the sound if you are as close as possible. Then as you go further this distance increases. So, it is the number of amount of, you know the millisecond value increases the number of time duration; that is what is called initial time delay gap; say imagine it is say forty millisecond 50 millisecond as you go further. Then you will have reflections say wall reflections; r 1. Then you may have feeling reflections floor reflections, further you know second third fourth, three part you know reflected in three areas; say for example, first reflection second reflection it reaches. Then it may go hit somewhere in the rear wall, side wall, and then it can come back.

So, you will have lot of reflections, and each of them finally, if you tally you will get it in few milliseconds, this is what we were talking in terms of, within 50 millisecond like clarity 50, or within 80 milliseconds clarity 80 c 80. Now an important thing which you have to control in designing an auditorium is the time difference between the direct sound and the reflected sound. Yes, we talked about you know whatever coming after milliseconds for speech performance, or after 80 milliseconds for music performance is not going to help you, rather it is going to mask the next signal.

So, what do we do, how do we solve this problem. Yes, I know now that c 50 is not desirable, it is on the higher side of it you know which is more than what the time is needed, or the clarity value is lesser; c 50 is lesser than what is required, c 80 is lesser than what is required, which means the ambiance is more initial, is much lesser, the signal is lesser. So, one attempt to solve this problem would be in minimizing the distance, the direct sound and the reflected sound, the difference between the distances between the direct and reflected sound. So, how do we again further do it?

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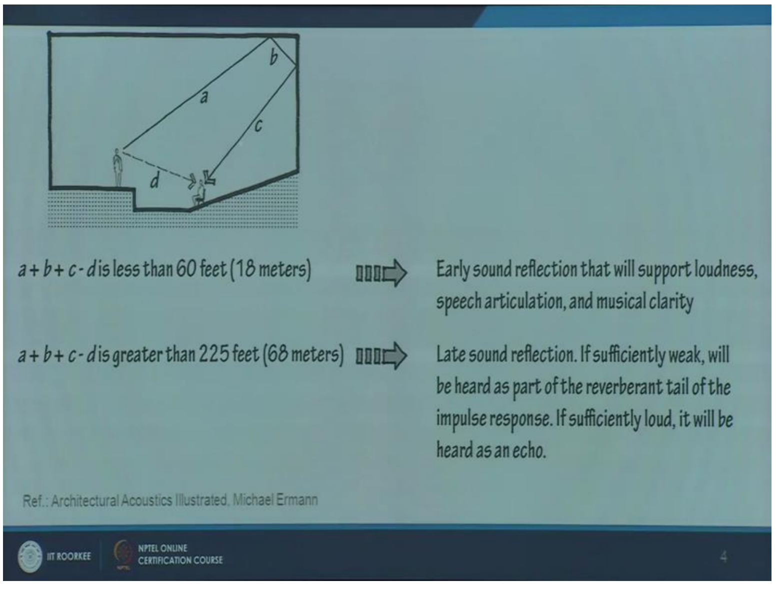

If I take a case like this; d is a direct sound speaker versus the listener, he is getting it in say you know 10 milliseconds, he is getting the direct sound. Imagine one reflected wave we are talking about reflections, there are thousands of reflections which might be happening. Take say first reflection say one it goes here path a, path b, and path c. This time say if it is 20 milliseconds this is for example, 80 milliseconds, the time difference between them is 16 milliseconds. Considering that you will have the direct and the reflected between them, 60 milliseconds which means if it is a speech performance, it is not going to actually benefit, rather it is going to mask the next sound sequence, whereas, if it is a music performance 60 million seconds difference is rather.

This is exactly we are trying to control here a plus b plus c this distance minus d is less than 60 feet, are 18 meters. So, actually here we are converting the time domain and the distance in terms of meters, length in terms of meter. So, taking say 340 meter per second sound velocity, the velocity of sound area say 1130 in terms of feet per second, then you will come to, say if you are calculating c 15, 15 million seconds it would travel 18 meters. So, if the difference is less than 18 meters, you will be able to receive the reflected sound also 15 millisecond - this is what ideally it means. If it is greater than 68 meters, there is lot of late sound reflection; the sound will be weak, because each signal is going to be masked by the late reflection. In order to avoid this you have to somehow control or enhance the early reflection. Let us look at how we do this.

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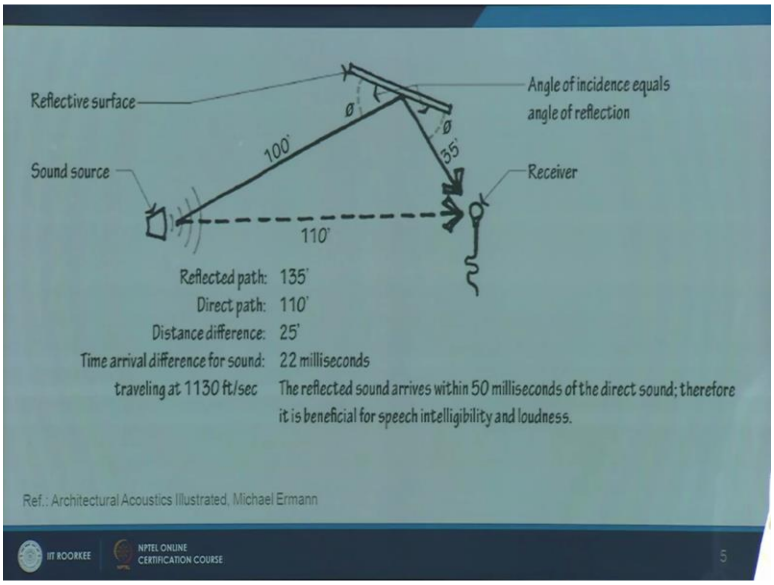

Imagine first scenario, a person is sitting here this is the source, you have a reflector. Typically in auditoriums larger auditoriums, you would have seen acoustic reflectors there would be hanging panels of different materials we are not getting into that material part right now. Imagine it is a reflective material or a reflective fabric; more or less it is specific frequency, again just to give you a very quick note. The material used here matters a lot, and may need also depend determines how a specific frequency sound is reflected. Another thing is the dimension of the thing itself. If it is too narrow versus too large which what frequency, at what frequency it is going to be effective.

Larger panels typically are effective for low frequency sounds, I mean there is also further iterative calculation methods formulas equations, using which you can also determine the width, as well as the depth of, or say length and width of these suspended reflections, reflectors. We are not getting into that detail right now, but we are trying to clarify the source path. Now, source direct and reflected path differentials; say imagine there is a direct sound the distance is 110 foot, the reflected path say this is 100 foot. Now a 35 degree angle, sorry this is 35 foot distance, reflected path again you now direct this is theta this is theta, incident angle is equal to reflected angle. So, this difference now works out to be 25 foot. If you convert it you get 22 milliseconds, which mean it is early reflection, which is actually enhancing your direct sound signal.

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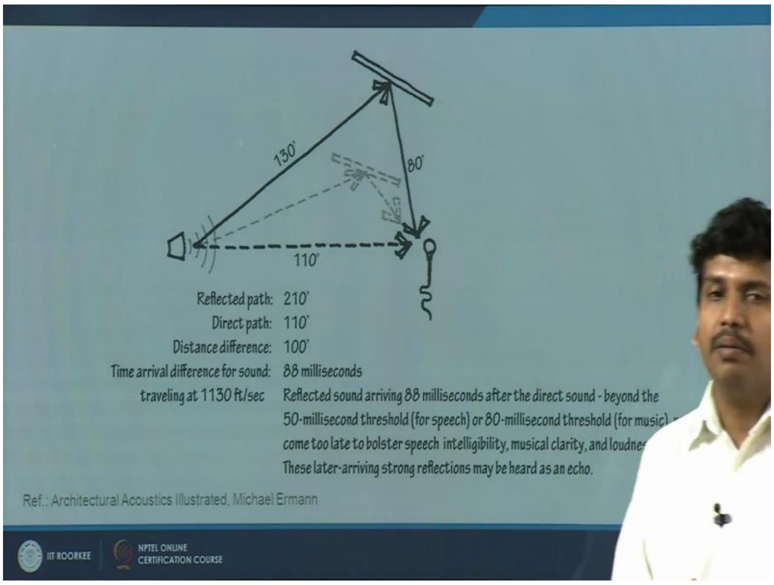

Now, let us push this reflector up little bit, let us take it further the height is increased now, more or less the tilt is retained, but the height varies. The direct path remains at 110 foot; whereas, now the reflected path, this is 130, this is 80 putting this together and subtracting 110, you have a distance difference of hundred foot, which means the time difference between the direct and reflected sound is 88 millisecond, which means they are, if it is a speech performance again, which we are interested in 50 millisecond, initial 50 millisecond arrival, it is short or it is excess by 38 millisecond, which is not desirable.

So, actually we have to contain this, initially we had arriving in 22 millisecond, which is you know good, but if you want to slightly increase it, you are now trying the second alternate, where you are taking it up here you are getting 8 millisecond, which means there is some place between this and this where it would be an optimum, that you can cut it to just 50 millisecond or lower, if you are interested. This also would be fine, but it also depends on the architecture of the hall itself, look and feel. You do not want the reflectors to be too close plus if the hall is large, it is not this one row of seat where the reflector is going to cater. It is going to cater for a few rows in an auditorium. So, you find that there is a lot of late reflection.

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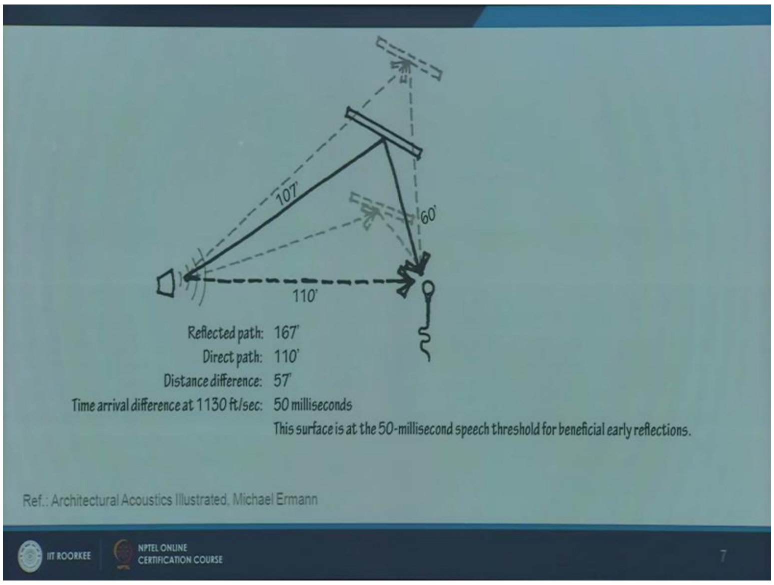

Now, you get to the third position in between this. You are fixing it at a point, where the time difference between, sorry the distance between length difference between the direct and reflected, works out to around 57 foot. This exactly would give you 50 millisecond which means up to this point there is a threshold. If you are going to take it further, it would result in lot of later reflection, but below this it is ok. So, this is a point where you have to draw line saying, the reflectors would be placed, somewhere here or below this point. For a single flat late kind of reflector it is OK, but when it comes to curved reflectors, it is getting eventually more complicated.

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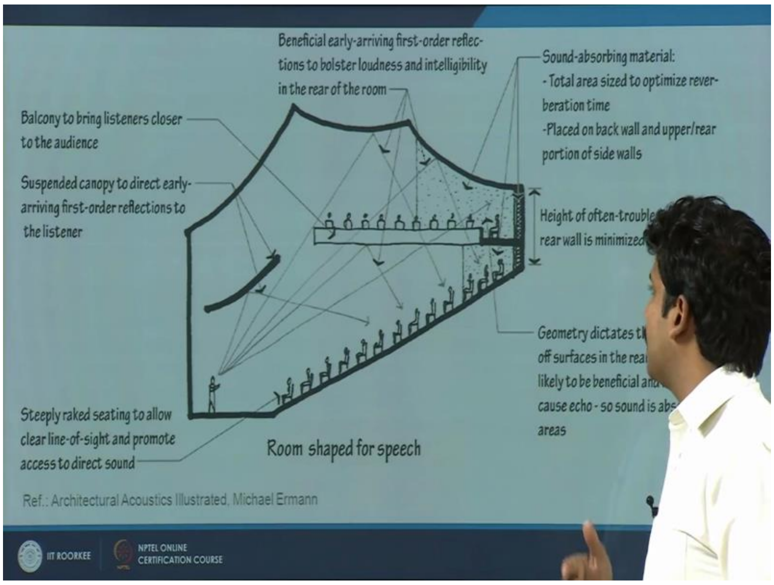

Now, these are called rate raising each and every sound rose. For example, if you are to design an auditorium like this. You will have to first define and design what are the reflections here, each of these points if you divide it into segments, each of these segment would reflect in certain angle. So, for example, in a guy here, sitting here the direct path versus the reflected path, you have to calculate.

Take another set say another five rows back, direct path versus the reflected path. So, here it seems for instance, then the next reflection might be from the balcony, or if you take a balcony seat here, you may have one reflection direct from the ceiling, it may also go further, and it may come this is section, this is you are seeing it in the sided, this is on the elevation, the cut section is here. If you are talking about this person he will get direct sound all the way, the distance, the time in millisecond would be higher naturally compared to him it will be higher. He will get reflected sound, he will get reflected sound; he will also get things from the rear wall. So, the longest reflection without much of decay, strong reflections have to be considered. I will show you a typical example, working example using a real auditorium. Apart from this, there are certain things called acoustic defects. Four commonly met defects are; first thing is echo, next another version of echo called flutter echo.

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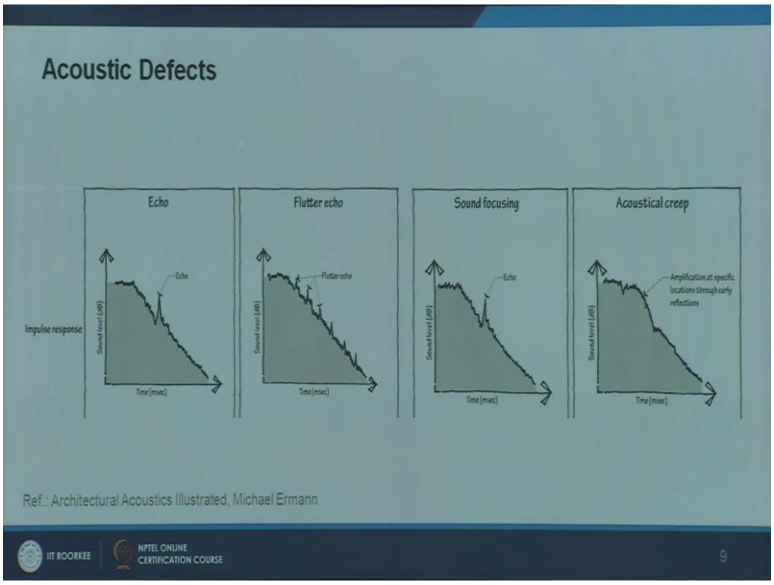

You have another phenomenon called sound focusing, and you have another one called acoustical creep. These are four commonly you know incurred acoustical defects which you find in a hall. Here you have to differentiate between echo and reverberation time, echo is also reflection of sound, but very sharp reflection. You know recollect the case we were talking about, there is a specific signal here, you are allowing it to decay down say by 68 degree for example, there is an eventual slope forming here. If there are specific wall surfaces which are reflective; say the rear wall, or you have a gallery V I P gallery. Typical auditoriums you have a V I P gallery box which is further straight to the stage. When a person is clapping, or when a person is strongly you know telling a word, spelling a word, there would be an eventual decay, but when this particular syllable hit's the rear balcony.

So, you have a stage Odeon here, you have the sitting arrangement, you have a balcony, then you have your ceiling somewhere. So, imagine you have a glass surface here, this particular thing is glass. If a person is spelling a very strong, or an impulsive source is produced, there is going to be a strong reflection, which will come back to him, you sometimes call it slap, acoustic slap. So, there is a very sharp reflection which is coming. On the other hand a regular kind of a reflection we were talking about would be reflected from here, reflected from here.

These are further smaller reflections, but there is one sharp point which is getting here and coming back. This would actually if you measure the reverberation time record it in terms of a graph, you would actually find a very sharp raise and then it is falling here. So, eventually it is giving you another sharp impulsive sound. So, you had a gradual decay of sound, but then there is another sharp impulse, then it is decaying down. This was your original sound, background noise level you made this impulse, it was decaying down, you find a sharp, then it is further decaying down, which means you have a problem of echo. You will be able to find it if you are recording the reverberation time carefully.

Another phenomena is flutter echo, typically occurs in conference rooms, many of the board rooms conference rooms have this problem. You have two parallel surfaces, you have say, a person say this is a conference room table, and people are seated all around. Specifically there is some impulsive sound which is produced, say if you are clapping, this will go get reflected, get reflected, and get reflected. This will not easily decay down, but it will be getting reflected and re reflected. So, a person seated here, he will first hear one reflection sharp reflection, first echo, then it would go hit and come back, he will hear the second reflection, second echo. It may be zigzag, but it may also happen in the same plane third fourth fifth. So, there will be lot of impulsive sounds which are happening one behind another. This is exactly what is shown here; gradual decay first second third fourth fifth, there will be a lot of flutters which are happening.

The third phenomenon is focusing of sound. Imagine the case of the circular hall which we were talking about. We talked about a specific circular space, with a podium on one side. So, what happens in this hall? If you are seated here, this sound gets reflected and re reflected from different points. So, what all these surfaces are doing; concave surfaces, they focus sound on you, if you are sitting here; say receiver one this is the source, everything is reflecting the sound, and channelizing it to one single point. The point focus point varies, depending on the angle of curvature. So, larger the curve the thing will form somewhere, the very short the curve is you will have more focused reflections, everything would focus here very short curves. This is something which is not preferable, this would also lead to decay then a sharp reflection, it may lead to echo, or it may lead to something called acoustic creep. So, if you are sitting here for example, we use another color, if you are seated in this point, the speaker is somewhere here, you will get a gradual flooding or creeping of sound, which is just a sweep kind of a signal, which is also not preferable. So, this instead of being smooth, this slope eventually has lot of undulations.

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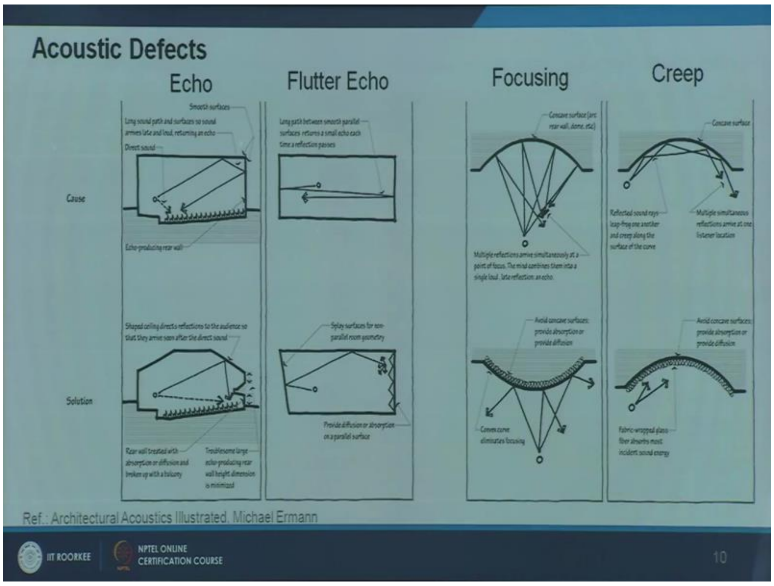

We will look at how they happen echo, as I said very sharp reflections. In order to avoid you have to either play around with the angle of the reflections, or you have to go for absorptive material, but typically echo is well controlled by modulating the angle of the surfaces, rather than putting more and more absorptive material, because it is also frequency dependent, and echo problems may not be completely solved just by acoustic material itself. Yes, there are methods ways of doing just using acoustic treatment, but best way is to pay attention more attention during the design itself. Number two is flutter echo, common phenomena which I was telling, an incessant you know reflection and re reflection across the plane; two methods again change the angle of the wall, do not make parallel surfaces, or you do not have to treat both the surfaces, treat one of the surfaces and make it more diffusive. Please remember you are trying to make it more diffusive not just absorptive.

As far acoustic focusing is concerned, the best way is to avoid a circular shape or concave shapes. Concave shapes are dangerous, both in plane form as well as dome ceiling both are concave shape which will lead to very sharp focusing, they have to be avoided. Once done if the architecture demands it or for some reason or the other say religious buildings where a dome ceiling is critically essential for example, the you know sentiments demand it you cannot play acoustical, you know card there, in that case there is a culture there is a tradition which is demanding you to build such spaces, then the next best alternate is to treat these spaces and stagger it, create more diffusion and absorption in these concave spaces, so that the focusing effect can be avoided. Similarly, for creep, best alternate is to either diffuse it stagger it or create absorption. You have to be careful on which frequency you are providing sound absorption that actually determines the effectiveness of the treatment itself. Other phenomena I will not call it a defect though I have classified or put it into this section I will not call it a defect, but we call coupled acoustic spaces.

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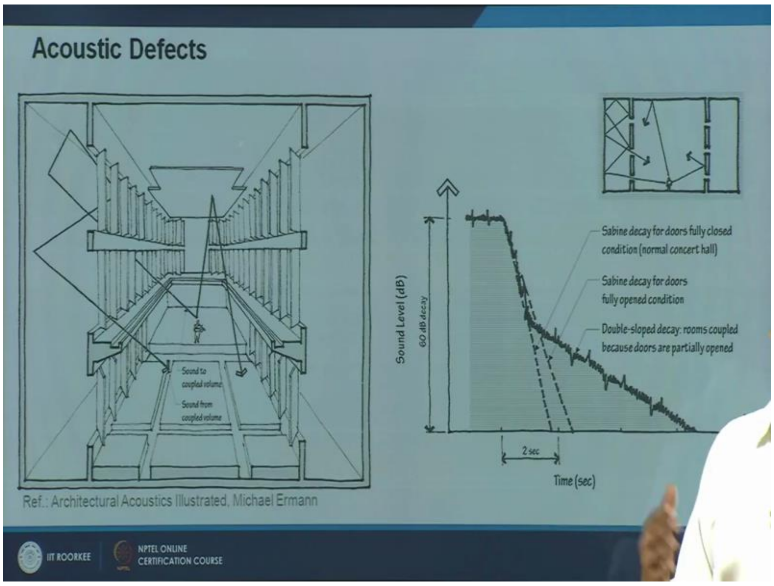

Imagine you have a room or a hall; you have certain type of lours. We can actually play around with the reverberation time. You need a larger reverberation time, the seconds the number of seconds have to be higher, then you can play around open close these lours or say if there are two rooms connected by a series of doors, you just open up the doors little bit. Now, you have one room, a meeting or a seminar room here. If it is such that you cannot treat too much, or you cannot do much around it, then you create an anti space here, an anti space here, create lot of voids.

You can keep them closed for one of the function say event one, when you have a specific desired reverberation time you keep these things closed, you get r t 1, for even two you need r t 2, just open up these things. In fact, you are trying to increase the volume of the room itself. The whole thing leads to double acoustical slope; say no double reverberation slope; first is decay slope. So, first is decay slope, first is this, there is a second slope. So, you have one space when you open up depends volume plus the number of slots you are providing, the slopes of decay changes.

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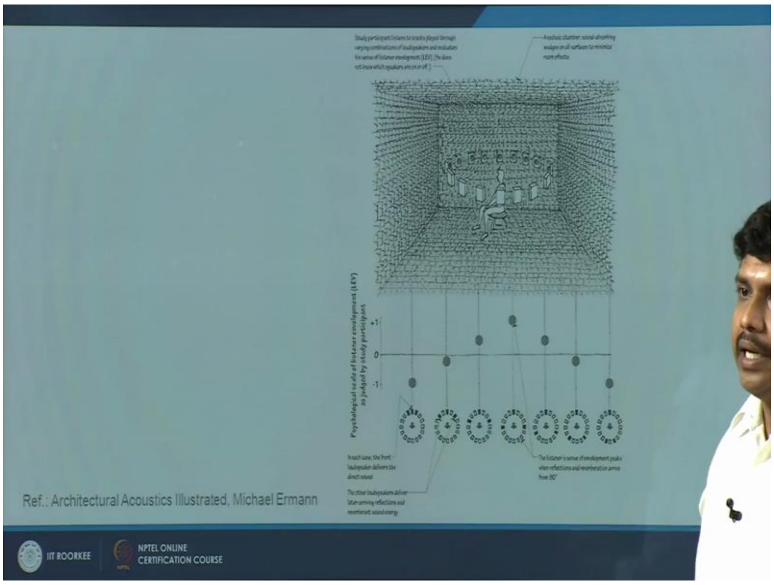

Other important phenomena I would demonstrate with the simple experiment which was conducted. This is a perfect an echoic chamber or a perfect absorbing chamber, where a person was made to sit. There was a series of sound amplification, or sound sources which were put around him. There is one direct sound say this is a plan, this is a view of it, the guy is sitting here this is straight what you see here, the darkened things, there is a dark versus empty the dark ones are where the speakers are on, these speakers are turned off whichever is dark those speakers are on. Say in this case one direct the first is always you know which is straight in front of his face, this is always on, in this case 1 2 and 3.

So, this is one second and third are on, say in this case this is on the two side one right and left they are on, in this case for example, this is on all others are off, but these two are on. So, kind of you are trying to ask him which sound you prefer, which is more directional and which is more diffused around you. See typically or listening to a music you will not prefer a very strong directional sound; whereas, for speech you will prefer a directional sound, and in some cases say you are listening some lectures one to one, if a person is talking you should know the direction from which he is talking, it gives you know more attention to be paid. Whereas, for music if it is more diffused, it is you know you call the phenomena called acoustic envelopment; that is exactly what I am trying to describe in this. In this experiment what they did, the results are here I will quickly tell you, this is a scale of envelopment as judged by the participant.

So, each and every participant is made to sit here. A specific set of speakers were turned on, and then they were asked to judge which gives them more envelopment, which is more better. So, hope the scale varies from minus 1 to plus 1, actually what people found was; one force here and two that is from left and right 90 degrees they found a good envelopment. Whereas, directional that is you know if you have these three on, or these versus these two on the envelopment was coming down. Envelopment is another important phenomena, this is just to understand the phenomena of sound reflections. Now we will move on to demonstration of an actual hall, where I will be talking about these parameters, this quality indicators which I had you know been discussing for the past two modules.

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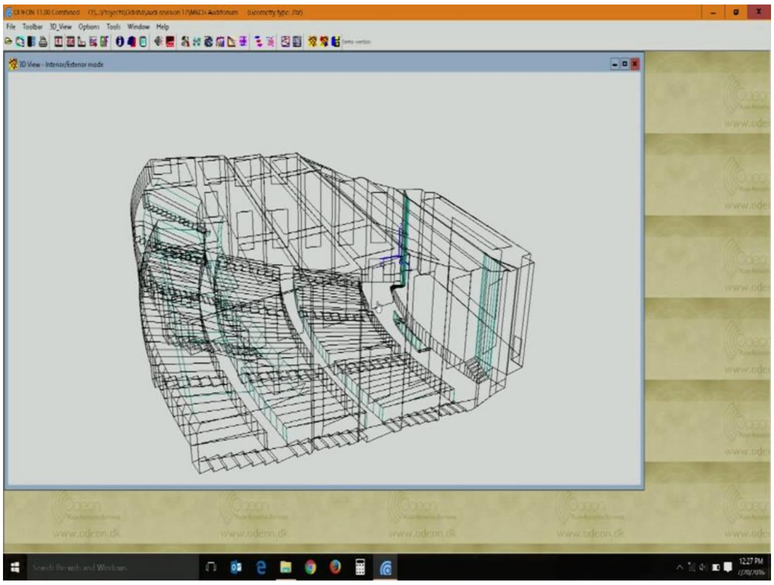

Now we will take a look at these acoustic quality indicators using a short demonstration. This software this is called Odeon, this helps you, know do these rate racing and specific detailed acoustic calculations, in a very interesting and understandable way. There are many other softwares for example, easel is another example you have Catt acoustics, there are lot of you know (Refer Time: 23:15) these are few examples of tools; similar you know rate racing another facilities are available, this is one such tool more or less the you know if you know the basics or fundamentals of acoustics, irrespective of the tool you work you will be able to get a better design. So, you have an auditorium here, this is a large auditorium here if you look at it closely, and it is a pretty long space it is around you know 2000 plus capacity auditorium.

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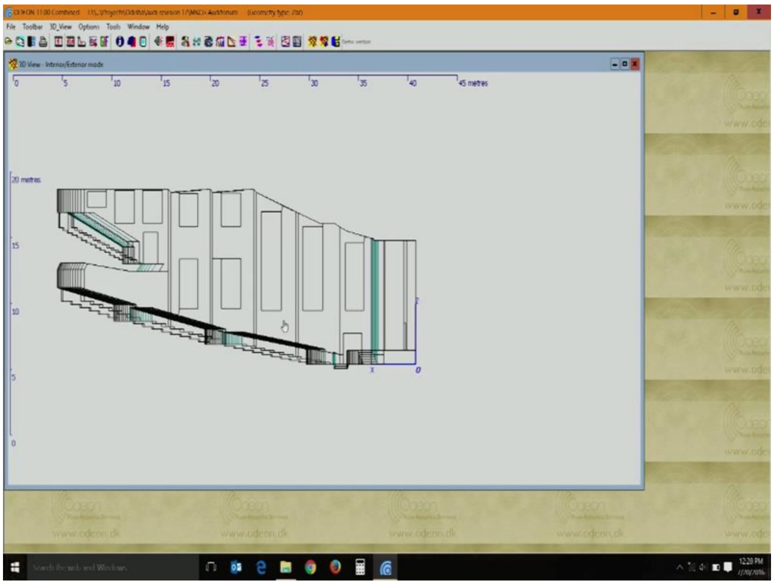

The height is also around 15 meter plus height, looking at the plan, this is what it is, a large volume space, look and feel of it, you have the center stage plus, you have the balcony this is the model which we developed in Odeon. So, you have the ceiling, and I am showing you more or less a finished, acoustically finished space. So, each of these colors actually in this tool, it represents the amount of absorption they provide, the darker they are the more absorption you get.

For instance there are certain lighter portions in the ceiling, they are gypsum panels, and they are not much absorbing little bit of absorption, again frequency dependent. There are panels where acoustical absorption is actually provided, plus you also have certain inclination of the ceiling, which was designed specifically for you know talking into consideration, the initial and late reflections, plus there are acoustical reflectors, plus absorbers provided on the side walls, you have a balcony and below balcony.

We will get into the details one by one. So, we had put lot of sources and receivers. So, what you see here I can show you the list of sources that. We had we had a set of speakers a line array system, hanging in the left as well as the right side of the stage. So, there are two line array speakers here, plus you have smaller speakers here below the balcony, what you see in red color; that is you know see here you have a set of speakers, if you look at it closely, there are a set of speakers in the front end, plus you have certain speakers below the balcony space. So, this is the arrangement.

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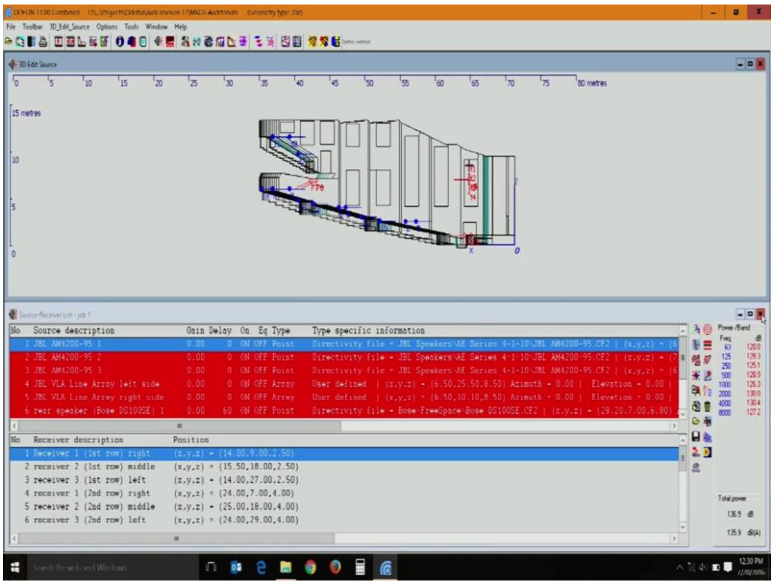

You have different description, you can choose any specific company that is not very you know essential that we are discussing now.

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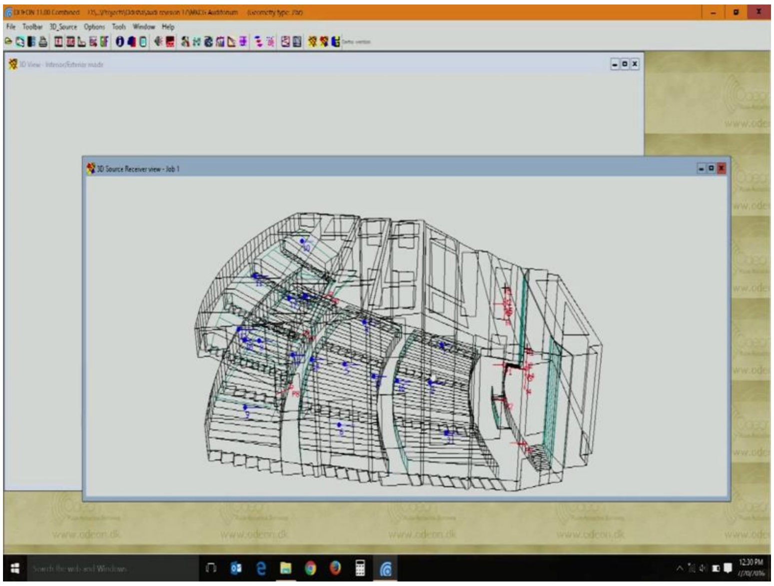

Plus there are these blue dots which where we have placed receiver. So, we imagine there are specific rows in which we have considered people sitting, below balcony, further extreme, front seat plus balcony at different corners say one side to the other side. The next part here is say first is to make the drawing by itself, physical dimensioning and drawing making the drawing itself is the first task; that is you know I am not demonstrating the tool here.

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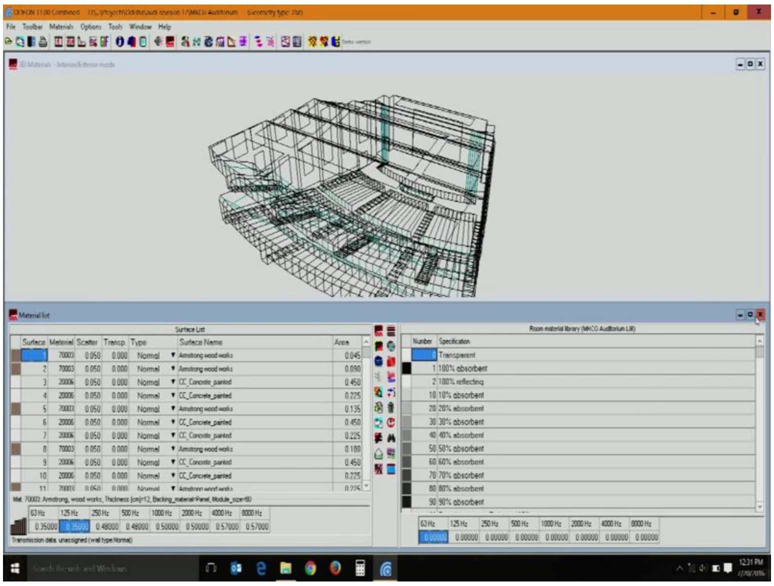

Next comes, the material specification. So, if you take a typical material. We are going to talk about absorbing materials later typical material, depending on frequency you see in this left hand corner, there is a material library from which we can choose, or we can add materials, depending on frequency the materials absorption considerably varies.

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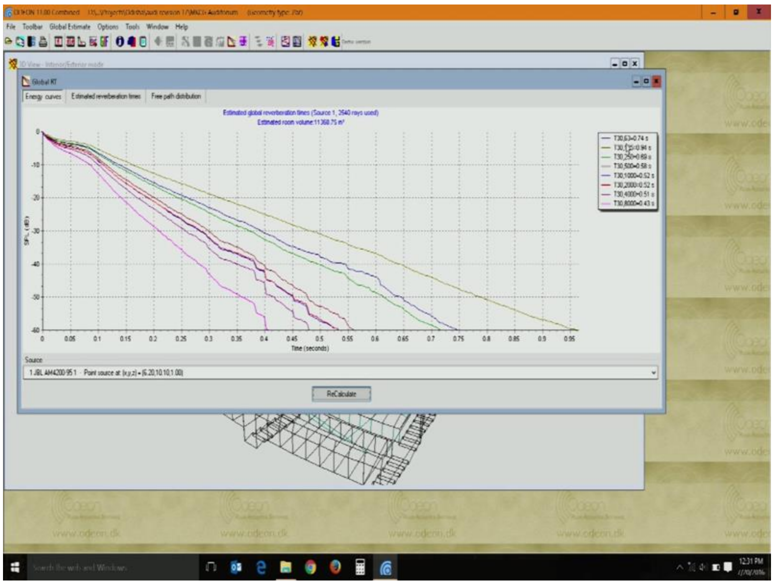

Then we can start estimating what is a reverberation time; that is the first thing, you can estimate t 60 or r t 60 at different frequencies.

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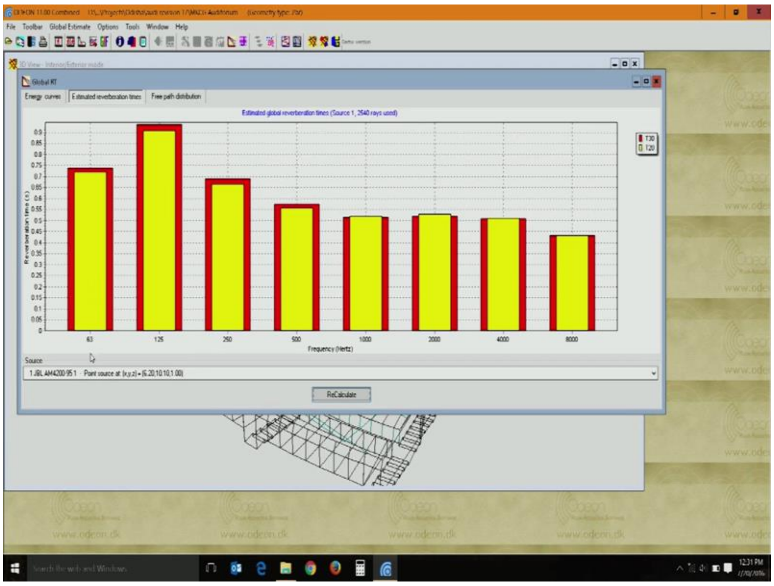

You get a fair estimate of, with respect to sources receivers you can get a fair estimate of what is your r t 30 or t t 20, and it also tells you how the path distribution is in terms of meter, and hit's how many hit the sound source are making.

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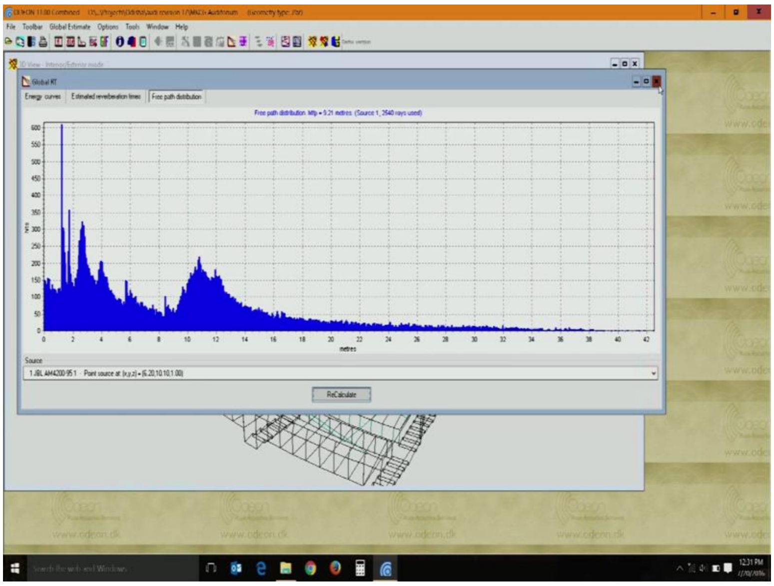

To you know give you a graphic representation. Let us go source by source, let us take the line array speaker. You have the speaker system here, if you take an x c z representation. Let us start over again.

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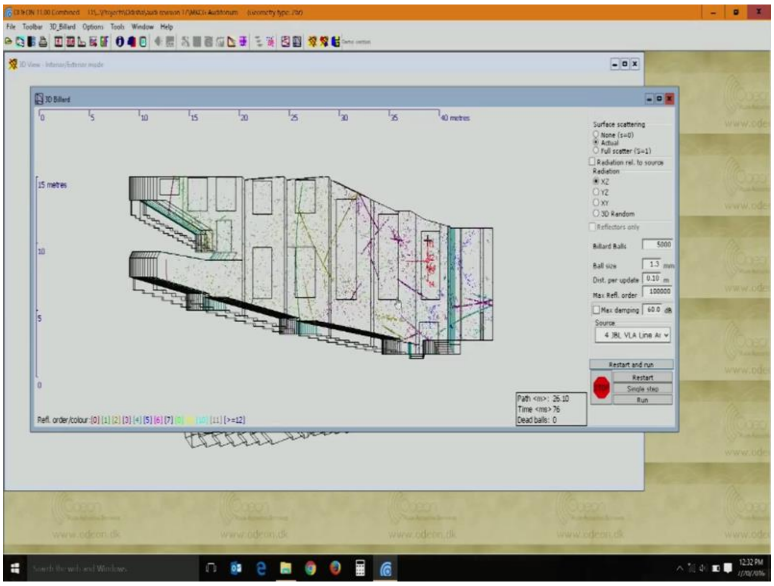

This is starting to emit, these are sound particles. By the time the direct sound reaches this person, there will be lot of reflected sound available here, and there is a running time in millisecond, and the path in meter. So, you know it takes about 80 85 millisecond for the direct sound to reach the rear part of the hall. So, I will quickly show you that. So, now this is propagating by the time it reaches probably the rear end. Now the direct sound is in the further end of the hall, it takes about 78 milliseconds, and it has traveled around 26 27 meters it is traveling to reach the rear row.

Whereas, here these are the order of reflection; that is number of reflections it has happened you know around 7 to 8 reflections have already happened in this area by the time you get the direct sound, which means you need amplification system if it is going beyond certain milliseconds; that is where the deciding point happens, where how many sets of speakers and how to design the amplification system itself, say line array speaker we have specific set of speakers to cater, say the lowermost probably would cater to this zone, the next might cater to this zone, then here, then one for the balcony we have certain amplification sources, you know behind the balcony also. This is the rear speaker; this is how the sound propagation happens. So, looking at it in three dimension this is how say further same, no arras source which we were talking about, a line array system, how the sound reflection happens in three dimension.

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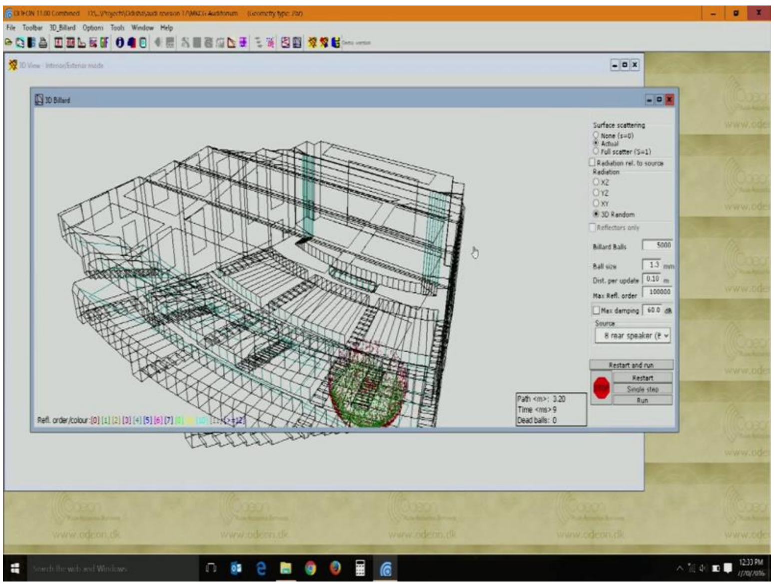

This is for a, you know plus you can count the time plus the distance you can be accounting for. We will get into the specific sound, how the calculations or you know results are looking like. Let us take one particular receiver, say let us take receiver number c 1 2 1 3. Let us take receiver number two, this is here all the sources are on, if you look at all the sources everything is on. This is receiver number two which is highlighted. I have already run the simulations here; I am just showing you specific estimates of numbers which I have got here.

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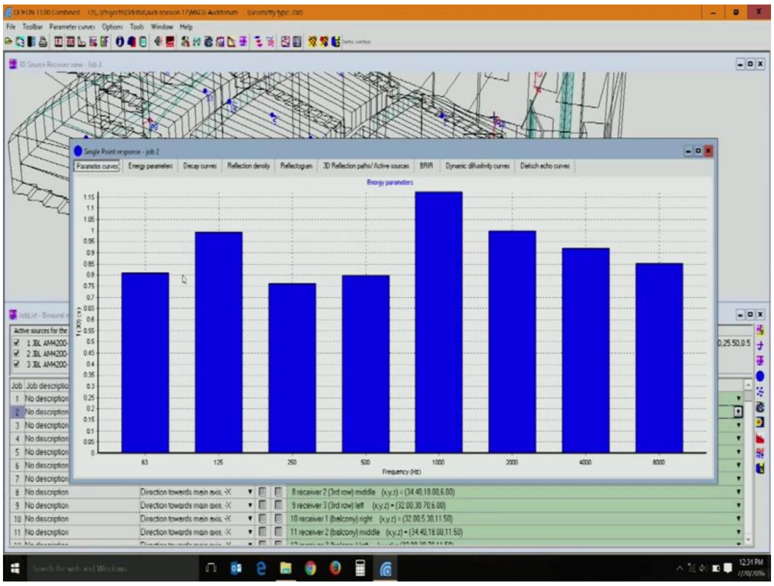

T 30 that is reverberation time 30 d b d k, these are specific frequency, you also get this for t 20 t 15 early decay time; t 30 looks like this. Then you also get different parameters like curvature, sound pressure level. This is definition d 50, this is clarity 7 c 7 c 50 c 80, we were discussing about c 50 and c 80.

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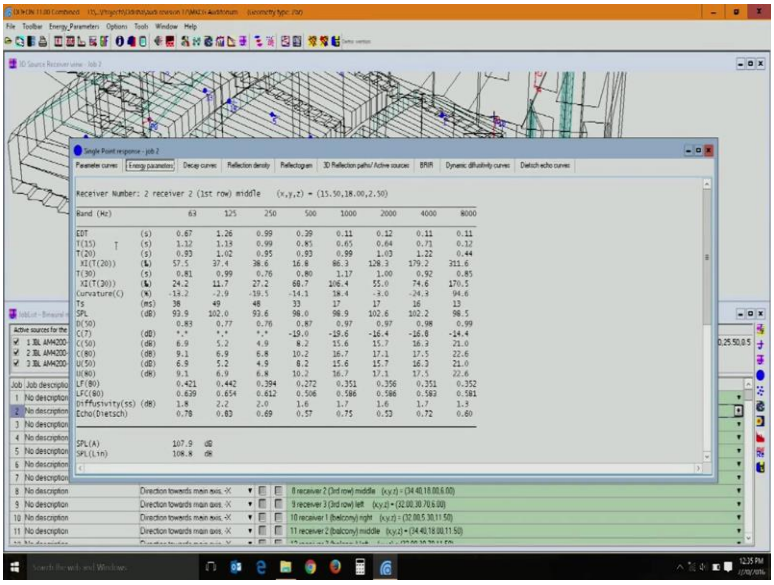

There are you know lateral fractions, diffusivity, echo probability plus you get a summary at this particular location. At this point what is the specific reverberation time what is the clarity, say let us take a look at the clarity values, say take at say thousand c 80, it is around 15.6. Now let us move to another receiver; say receiver number 40. So, where he is sitting here, receiver number 14 is I do not have, probably we can look at, receiver number 5, and receiver number 5 is little behind this place. If you look at the same, the numbers are starting to vary. So, the clarity which this person experiences in this point in the front row, would be different from what you get somewhere in seat number 14, or seat number 5 or further behind sometimes in the balcony, you would start experiencing the differences, this is number one further summary of tables. Then you have the decay curve, important parameter which we need to look at now, something called reflectogram.

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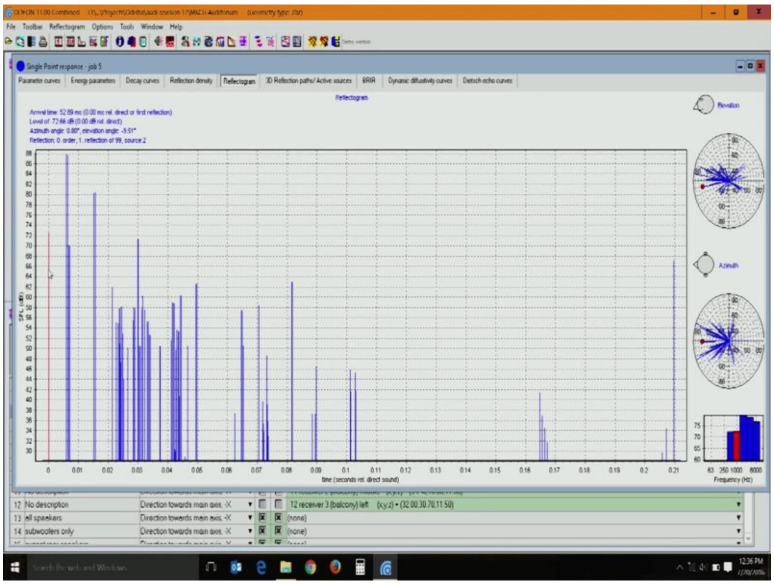

This is very essential in designing acoustical; you know quality of a space. This thing is called reflectogram, something similar to what we drew on the board. Here you have time, in this point you have time in seconds, this is on pressure level what is selected here, the red one is a direct sound, zero that is the first arrival, following that you have lot of blue lines, which indicate each reflection, reaching the particular receiver. Now we are talking about receiver number 5, instead if you go back to say receiver number two or receiver number one for that matter, this reflectogram will considerably vary, from one listener position to other listener position; say we are not talking about the listener 0.1. So, the person is sitting somewhere in this corner close to the corner.

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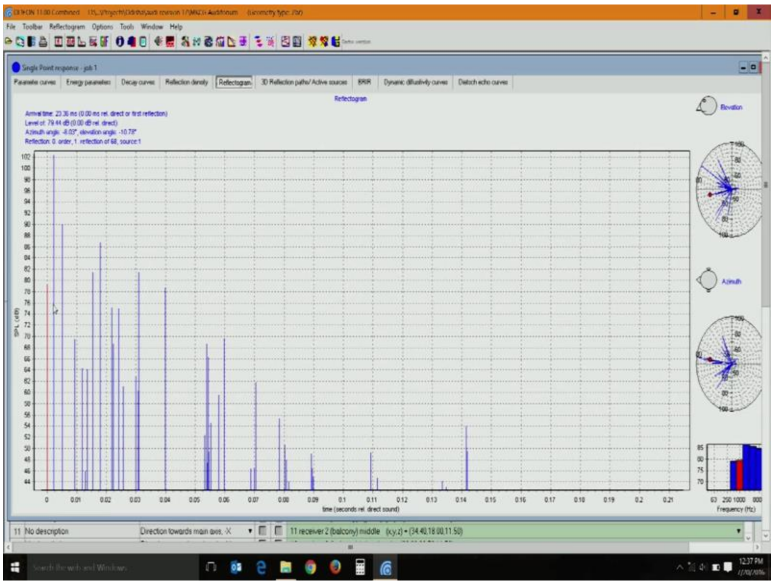

This is the direct sound, then he gets the first reflection, this is the second reflection third fourth and he starts getting reflection. So, if you are interested in musical performance, you will probably as I said stop at 80 milliseconds somewhere here, whatever comes before is good, whatever comes later has to be avoided. Now the late reflections are relatively less. Now if we move on to another receiver for example, a rear side person, who is sitting somewhere, we can even take the same number five, fifth receiver

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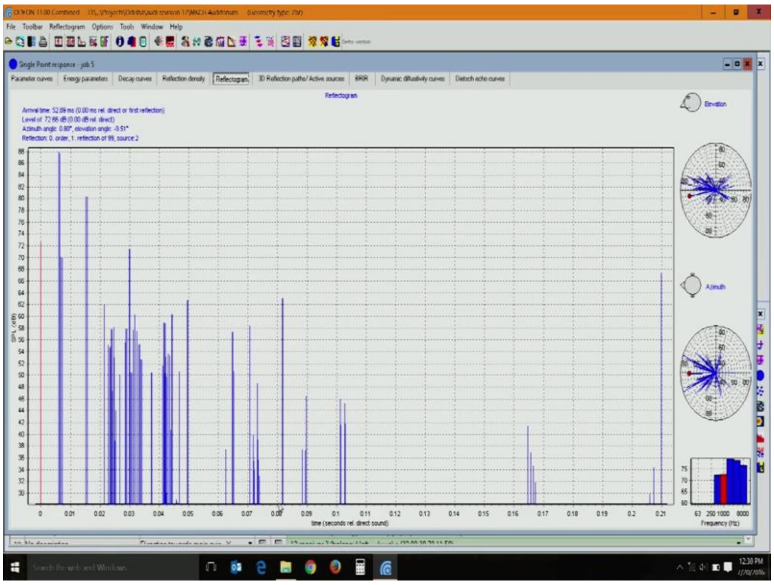

You look at the reflectogram. We saw it is starting to differ after 80 milliseconds still you have sharp reflections coming.

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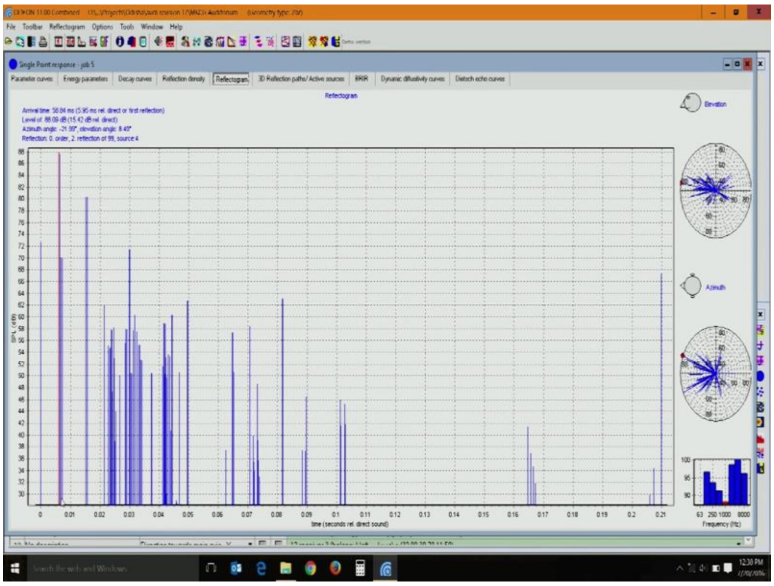

Now, let us look at what are the reflections where are they coming from. So, this is zero, this is the first reflection which you are getting. You can actually visualize in elevation as well as in plan, which direction it is coming from, and where it is actually coming from at different frequencies as well. So, this particular reflection you can visualize, it is looking like, this source is here, one of the line array sources, the direct sound is here plus the reflected sound. If we take a look for instance, let us take further reflections to get more clarity.

So, you start getting reflections from the side walls plus the floor plane further on. It will actually pictorially give you; see there is a reflection happening in the rear wall, it travels to the side wall then it comes here. It is kind of an estimate of where the reflection is also happening, say if you feel there is a strong sound, this is decibel the initial source was around 73 d b. Now you are getting a late reflection which is around 64 65 d b; say 64 decibel which needs to be avoided. This is a very strong reflection. If I have to avoid this particular reflection, then I will have to treat either the rear wall of the stage or this particular side wall.

If you take a close look we have put certain absorbing panels, but then if you have to address this particular receiver, the treatment has to happen here or here, so that this particular ray can be cut off. Likewise you can take few specific sampling points and start working here. You also find specific late reflections far off. They may not be much critical, because in terms of sound pressure level they are pretty low. There is one more strong reflection here end of it, very you know far in time.

It may also appear that you know it strikes the rear wall, there are two three more reflections which are happening across the hall. It may not be probable that it would hit all the way and come back. You know it is a judicious choice a person has to take, between the surface in which it is reflecting in, the path it which in which it is traveling, and how much intense the sound itself is, the reflected sound itself is. So, reflectogram typically helps you find out where specific reflections are happening, and you can graphically avoid, no redesign the space itself and graphically find out, whether the new design or new shape, would enhance the reflections or not.

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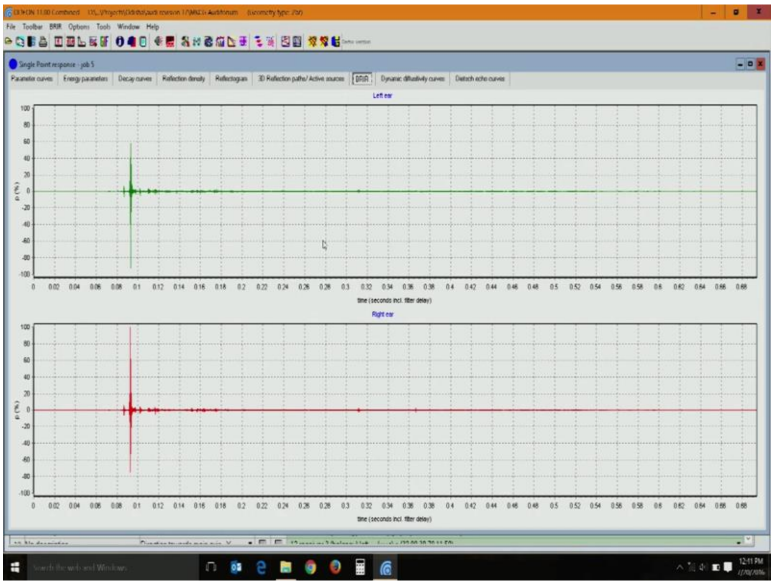

Then you have the binaural thing which is called binaural. So, two years both of them should actually get the reflected, as well as direct sound more or less in the same time, there should not be much of the time difference between the sound received in the left ear and the right ear. So, keeping in this, keeping this in consideration the binaural graph really helps. This actually gives you at what time, this is time in x axis, what time your left ear and the right ear start receiving the signal, and how sharp they are, plus you have the diffusivity curve.

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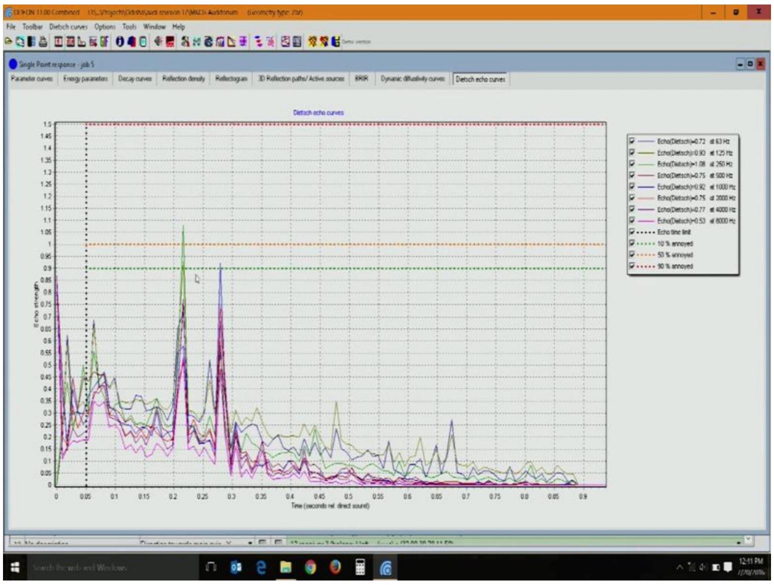

There is the echo probability curve, if it goes brain beyond the threshold say, 50 percent threshold; there is a probability that 50 percent of the people might be annoyed with this particular sharp reflection. So, looking these images plus the numbers, taking them into consideration, we can start working and reworking on the acoustical design.

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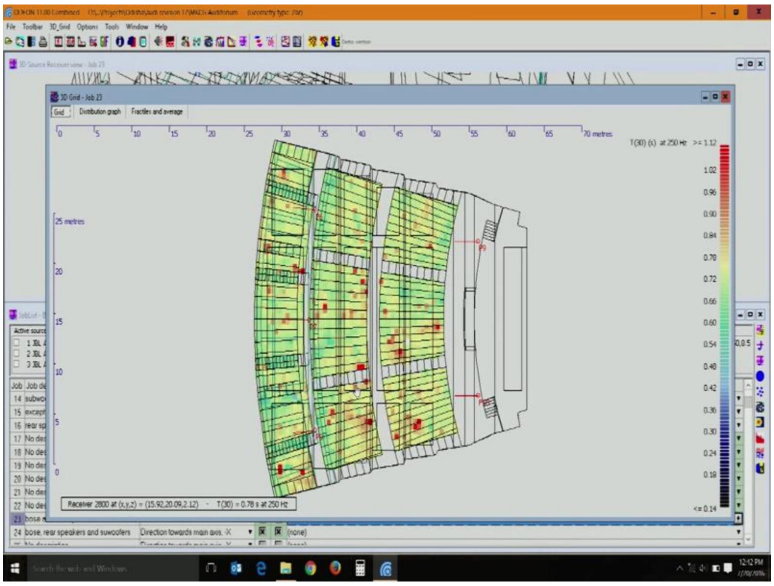

Let us take a look at few more quality parameters which we had, I am going to show you a three dimensional mapping, which we have done here. Let us specifically choose certain parameters and look at them. I will go to a plan view, and let us take a look at say t 30, at say 250 hertz, the reverberation time which we get here is around 0.8, and it also at specific points, there are reflections, because of which you get a slightly increased reverberation time, but more or less you get the distribution graph.

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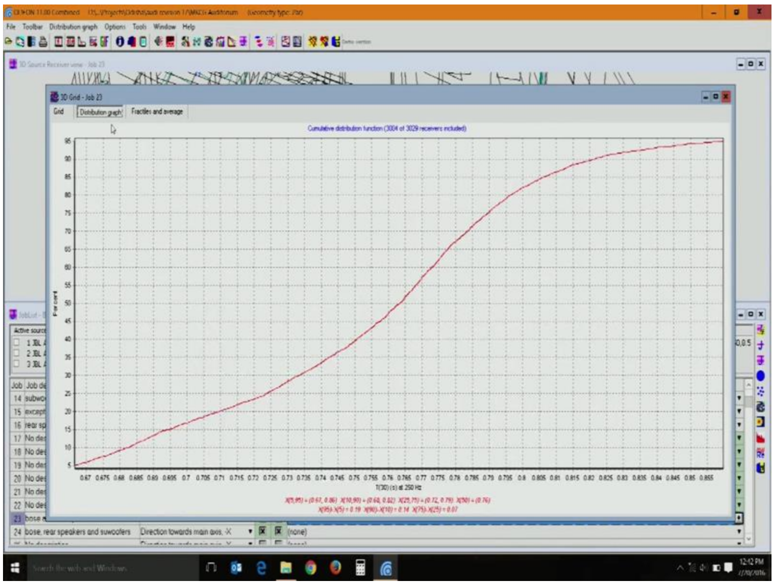

More or less the reverberation time at this frequency is ok, at say thousand hertz it is further coming down, at higher frequency it will eventually drop down; the next parameter that we looked at to be more relevant.

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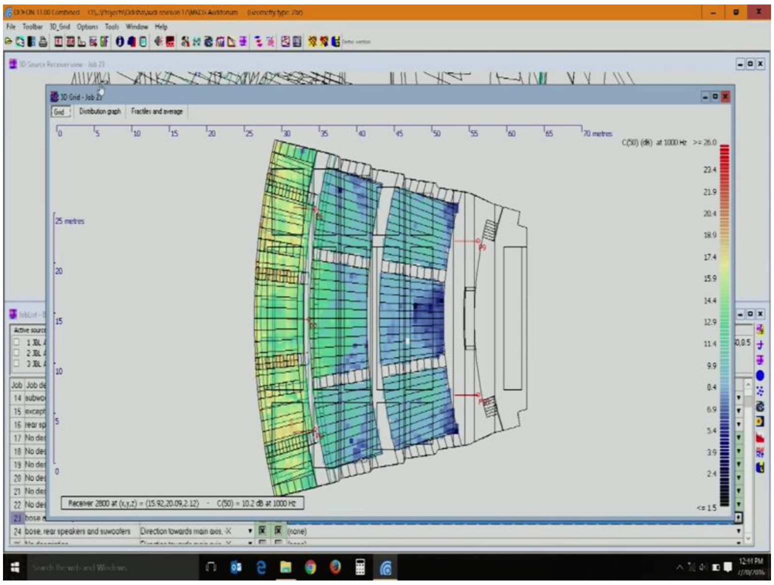

We looked at clarity c 50, you will see that there are two different clarities which we are getting; one in the rows here, and this one is below the balcony. This actually becomes a double space where the absorption condition in this place, in this zone are different, because the volume is different plus the one below balcony, the volume is pretty less, the absorptions are different. So, the clarity is higher. It does not mean this is good. It is not also preferable that there is a starking difference between a row here and the next row here, the clarity is kind of distinctly different. We have to try and maintain uniformity, according to that, if you go by that motion then, ideally we will have to bring down the value here maybe introduce some reflective components or reduce the absorption here, volume you cannot naturally do things here.

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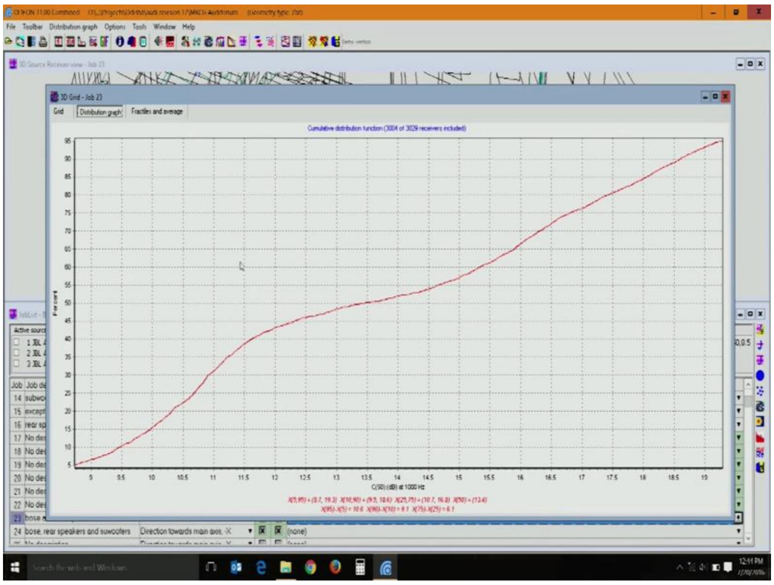

So, eventually you have to get the distribution more proper, this kind of distribution may not be very preferable. So, clarity part it has to be adjusted.

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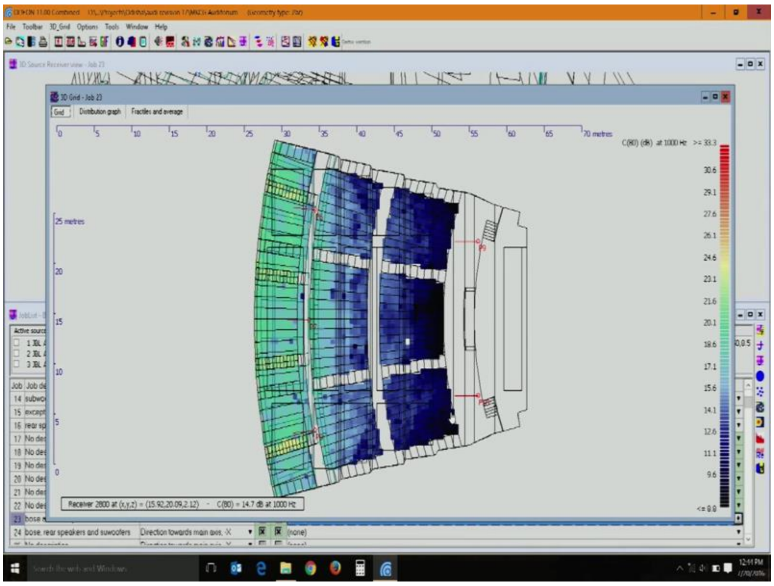

Again you can look at different frequencies. So, if you look at a c 80, initial this part you have a different clarity, eventually it varies and then it goes up pretty much higher here.

So, this indicates that there is a reworking required in terms of clarity. One of the iterations that is the result I am showing you, after this further you know certain enhancements were done. Then there are other parameters like lateral fractions that I told you. We are not discussing these technical terms and where are the probability of echo higher, at which point echo might happen, maybe here. There is more probability of echo these places, there is no much probability

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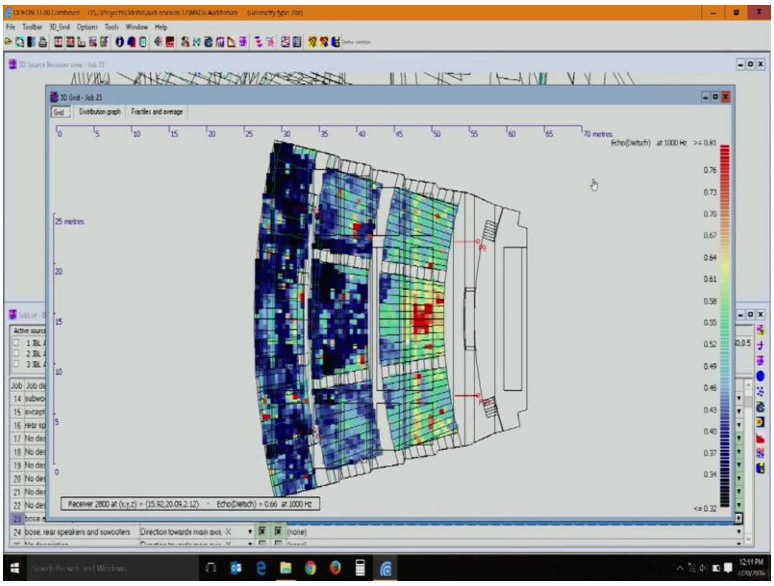

So, we can actually look at these parameters and start designing it.

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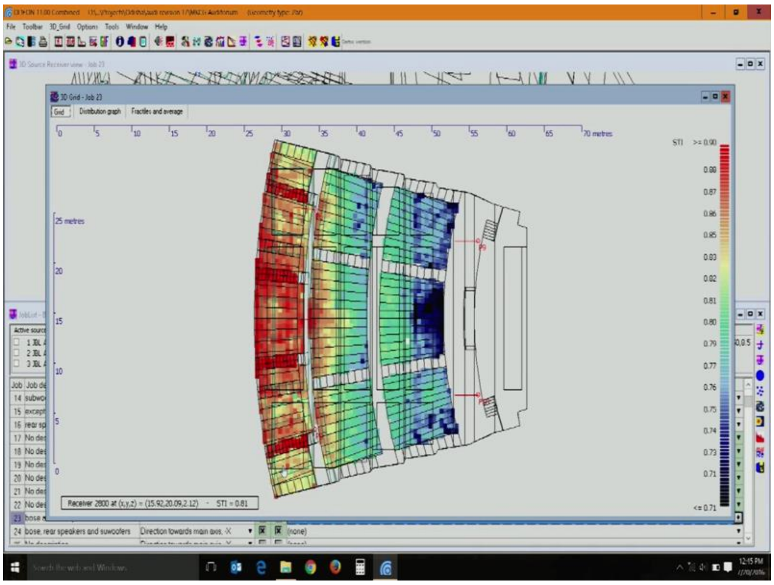

Then we have our speech transmission index which we looked at it S T I. Here the S T I is pretty high and in the front portion somewhere here, the volume is pretty high, the ceilings you know is quite high; S T I is slightly lower. Though it is not really low it is somewhere around 0.7, which is not bad, but still if you have to increase or improve this, you might need certain either sound reinforcement has to be adjusted or you have to go with certain reflectors and absorbers, so that the signal (Refer Time :40:16) ratio can be adjusted. This is rusty again; specifically for amplified sounds you have certain average quantities. So, this is all about, how specifically numbers which we study in theory, apply in the practice. So, taking a typical hall, any small large volume auditoriums, starting from lecture hall conference room to large volume auditoriums, these numbers or these indices which we looked at quality indices are critically important.

To conclude this session we looked at general design considerations what are the common things we looked at, designing of acoustic reflectors, what is the principle behind designing it, and we also looked at a few acoustic defects which are common, and we also looked at another thing called envelopment, where you know this is typically to give you an idea where to put your speakers, or where not to put your speakers. Yes, it depends on the type of performances; it is more challenging for multipurpose halls. If it is just meant for say an orchestra it is fine or speech it is fine. Whereas, if it is for multipurpose hall it is going to be more challenging, and then we looked at the demonstration of Odeon acoustics, it is a software tool through which actually the parameter, quality indicators were demonstrated.

Thank you.