Fundamentals of Acoustics
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Lecture – 64
Weighting

Hello. Welcome to Fundamentals of Acoustics. Today is the fourth day of the eleventh week of this course. And what we planned to do today is discuss weighting of sound pressure level. And what that means, and why is this important is the subject we will consider in detail today and may be also tomorrow. So, the theme of our discussion is weighting.

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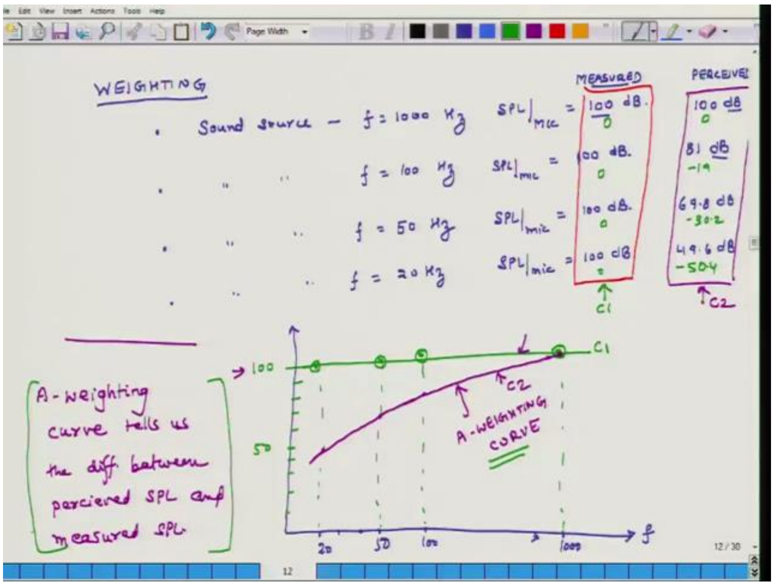

So, let us make some important observations. Suppose, I have a sound source and that sound source is emitting sound at 1000 hertz and I use a microphone to measure that sound pressure level for that 1000 hertz tone, and let say that the SPL is 100 decibels.

So, sound source frequency is 1000 hertz, SPL and how are we measuring this SPL through microphone is equal to 100 dB. This is the first case. And then we are measuring it through dB through a microphone, and then we are also asking a listener to listen to it and we tell him that- this much sound which was hearing at 1000 hertz it is at 100 decibel level.

So, this is measured and this is perceived. So, this is perceived at 100 dB. Then we do another experiment, we take a different sound source such that its frequency is let say 100 hertz. And we adjust the sound source in such way that its SPL as measured by mic it is still 100 decibels. Now we ask the listener that look earlier we have listened to a 1000 hertz sound and it was set at 100 decibels now we want you to tell us that, what is the sound pressure level of this source? We do not tell him its 100 decibels as measured by mic, but we ask him what do you think is the sound pressure level of this source. And you ask a lot of people and his perception will be that for 100 hertz tone will his perception will be somewhere around 81 dB. What does that mean? That his ears are more sensitive at 1000 hertz and at 100 hertz they get excited to a lesser extent. So, they are lesser sensitive, and that sensitivity dropped between 1000 and 100 hertz is 19 decibels it has gone down.

Now, we do another experiment. So, instead of 100 hertz we play a third tone. And we again produce; we again said the strength of the signal such that the measured SPL from a microphone is 100 decibels. And we go back and ask the listener what do you think is going to is the SPL of this, and his perception if you do a lot of status you know you take several listeners and record your observations his perception will be something like 69.8 dB.

So, his ear sensitivity 250 hertz is less than that 200 hertz and even lesser than 1000 hertz. So, his sensitivity is going down from 1000 hertz downwards. And we do a fourth experiment and here f equals 20 hertz, our microphone says that the sound pressure level is 100 decibels and the perceived sound pressure level is further in to less 49.6 dB.

So, let us make a graph. So, this is 100 hertz, this is 1000 hertz, this is the frequency on the log scale. So, 20 and may be 50 will be somewhere may be somewhere here. If I plot this column then; so this is constant at 100 dB SPL. So, this is this column C 1. And next I plot this column C 2. So let us first, this is 100 this is 50, 10, 20, 30, 40, 50, 70, 80 90. So, if I plot this column C 2 here its 100 decibels, it is 80 decibels at 100 hertz or 81 decibels at f equals 50 hertz; at f frequency 50 hertz it is about 69-70 hertz. And at f equals 20 hertz it is about 50. So now I will join this. So, this is the curve for column C 2. This curve is called A -weighting curve and I get a more accurate curve if I plot for all values starting from 10 hertz to 10000 hertz, here I have just plotted a section of this curve.

What does this curve tell us? It tells us how different is the perception of human ear compare to the perception of a standard microphone which has constant sensitivity across the whole bandwidth. So, A -weighting curve tells us the difference between what, perceived sound pressure level and measured sound pressure level. And here my reference is 0, but in the actual reference; so here my reference is 0 flat line is 0, no sorry here my reference is 100 decibels, but in actual A -weighting curve we do not take the reference as 100 rather we take the reference as 0 decibels. So, if it was 0 decibels then this would be 0, this was 0. So, if all this was 0 then this would be minus 19 this would be minus 30.2 and this would be minus 50.4.

So, if I plot this revised curve which using numbers which are in green then I get the actual limiting curve. This curve is somewhat similar the shape will be same right, but it will just get shifted by a constant amount. So this is A -weighting curve, and this curve tells us how different is the perception of human ear to sounds at different frequencies relative to the sound pressure level measured by a standard microphone.

Now, let us look at this curving detail.

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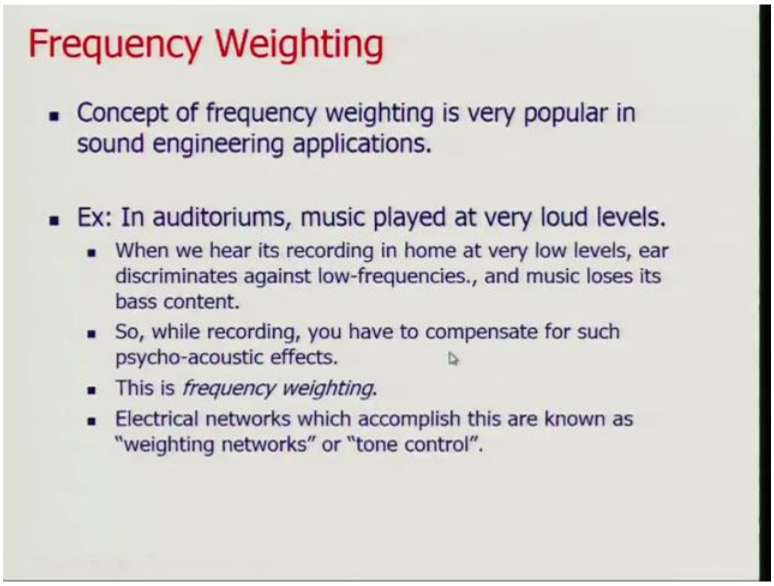

So, let us look at two slides. So, this slide is about frequency weighting. So, what is frequency weighting? It is very popular in engineering applications.

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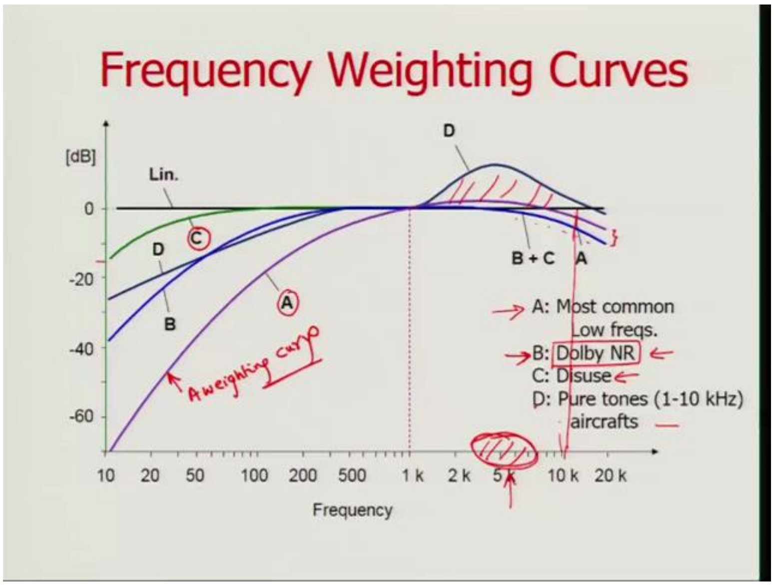

And this is the A -weighting curve. And what this curve tells us is; how is the human perception of sound at different frequencies, how is it different compare to the measured value of sound pressure level. And please note the x axis is on the log scale as well as the y axis is on a log scale. Now, you see also that there are other weighting curves also, we have talked about A -weighting curve, but there are other weighting curves also C weighting, D weighting and B weighting. Now it just happens that in past all these different weightings for used, but in modern days definitely C and D though are not used that much, but I will still explain what these other weighting curves are about.

So, first we will look at the C weighting curve. So, there will curve in the green is C weighting curve and this green curve also comes and gets overlapped with the blue line. And the blue line is D weighting curve. So, C weighting curve is not used a lot, but what this curve tells us is that above 10000 hertz; so our A –weighting, so this is 10000 hertz. Above 10000 hertz if we do experiments which I had talked about earlier, we feel that above 10000 hertz the difference between perceived sound and the actual sound is not all that much. So, based on that people developed the C weighting curve, but now it is not used a lot. So, I am sorry not above 10000 hertz above 100 decibels. So, the difference is lot when the sound pressure level is less than 100 hertz, but if you play really loud sounds then the difference is not all that much.

So below 100 hertz, see here the difference is at 10 hertz it is almost 80 decibels at 10 hertz, but if you play the same sound instead of at 100 decibels you say play at 150 decibels you will say perceive that the sound level is only minus 15 decibels. So, above 100 decibels thus difference between perception and measurement is not that much as you changing the frequency. So that is why the C weighting curve is which is in green is much more flat, but this is valid only for very high sound pressure levels. And because most of the times we do not use these high sound pressure levels this C weighting is not used and it is out of practice. So, that is C weighting.

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Above 100 decibels. So, the next curve is B, let us look at B. So, this is B and this is blue line. So, what does this B weighting curve? This is based on some important observations that in this region 4000 to 7- 8000 hertz. Even if you play a tone even if you play this tone slightly at a high level, so let see you play a tone at 6000 hertz the ears are extremely sensitive to a noise around 6000 hertz. And if you play this at an extremely large level our ears because they are very sensitive our ears can get damaged.

So, in a lot of sound recording industry even if you have small noise around 6000 hertz and if it is not reduced the noise around 6000 hertz is not reduced sufficiently the recording when the person plays he will think that it is of bad quality, because around 6000 hertz the noise the sensitivity of our ears is very high. So, what you see here is that between B and A here this difference. So, you must have heard this Dolby; noise reduction algorithm here is a company called Dolby. So, what they do is that around 6000 hertz they discovered that if you reduce the noise level in this band when the sound quality of the recordings perceived by the listener it is perceived to be pretty good. So, in this region; so that is what this B weighting curve is. And this is especially effective in this bandwidth around 6000 hertz.

And then finally we have this D weighting curve and this is also not used the whole lot, but earlier they used to use it particularly for aircrafts. And in aircrafts there is a lot of high frequency noise, because turbines and things are air rotating it very high speeds. So, there is a lot of high frequency noise and they wanted to ensure that the pilots their ears did not get damaged because of exposure to high frequency noise. And high frequency noise can occur also around 6000 hertz. So they said that- oh this is our perceived sound level so if I reduce in this region the overall sound pressure level then ears will be better protected. So again, but nowadays most of times we usually use this A -weighting curve, B is used especially in European industry and also in some American industry when they are trying to reduce noise, but C and D in general are not used a whole lot.

So, that is one part of the discussion. And the second thing I wanted to talk to you about is how do you calculate these weighting factors. I will give you a mathematical relation for A -weighting.

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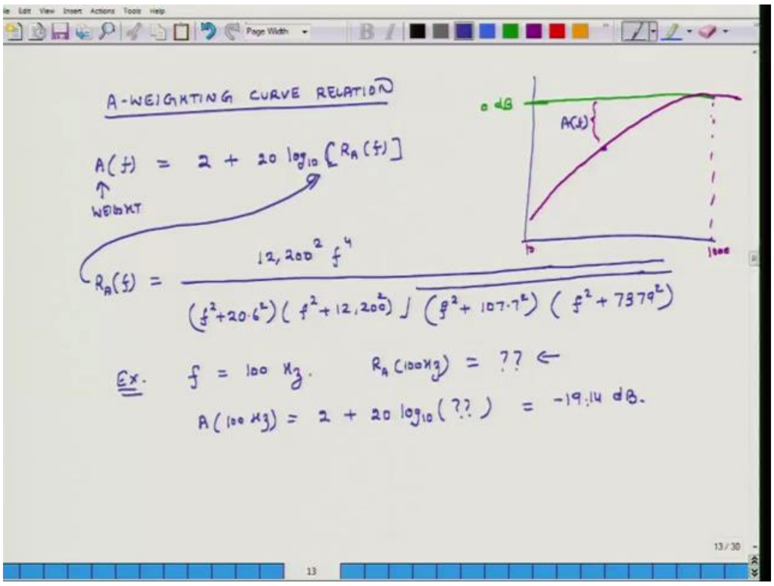

A -weighting curve relation' so what will this curve give us? So, let say our reference sound level is 0 dB and this is our A -weighting curve. So, this is 1000 hertz, this is 10 hertz. So, suppose I want to make corrections to sound pressure level so that they reflect the perceived sound pressure level. So, for that I have to generate this curve, purple curve then at whatever frequency I have some number of decibels, so then I deduct this much amount at each frequency right. So, the curve for this thing can be gotten from this relation. So A, this is the weight, so that this is A f which is the difference from 0 decibels to the purple curve. And this is equal to 2 plus 20 log of 10 of a number R A which changes with frequency.

So if we know R A, this function R A which is the function of frequency we can calculate this A -weighting function which changes its frequency. And what is the relation for R A? So, R A which is the function of frequency it is a complicated formula, so 12200 square times frequency to the power of 4 divided by f square plus 20.6 square times f square plus 12200 square times f square plus 107.7 square times f square plus 7379 square. So, using this function formula R A function can be evaluated and if we plug this R A in this I can calculate A -weighting curve. We will just do very quickly for one or two numbers.

So example: let say if I want to find what is the difference between perception and sound pressure level at 100 hertz. So, for 100 hertz first I calculate R A at 100 hertz and when I use this formula it comes to be 1069 and then my A -weighting at 100 hertz is equal to 2 plus 20 log of 10 of 1069. So, this comes to be minus 19.14 decibels. Actually this number is incorrect because if I take log of 1069 it will be three times 20 is 60 plus 262. But you please go back and calculate this, and plug that number here so let that b your assignment and we will also ask that in the quiz for this week. So, I have done the math, what you have to find is R A which you plug-in here you get 19.14 decibels.

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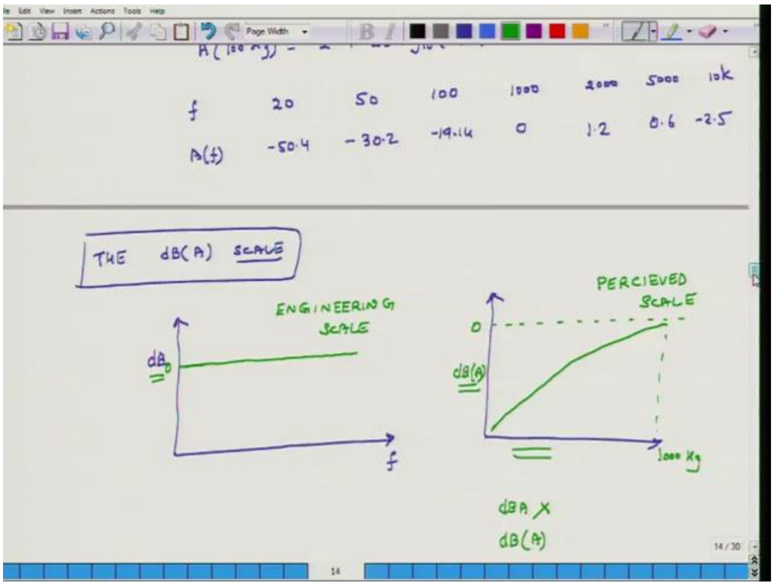

And when I do similar numbers f and let us write down at 20 hertz, 50 hertz, 100 hertz, 1000, 2000, 5000 and 10k. My A f that comes to be minus 50.4 minus 30.2 at 100 hertz its minus 19.14 at 1000 that is our reference so it is 0 decibels. It is 1.2 decibels at 2000, 0.6 at 5000, and minus 2.5 at 10k. So last thing, the dB A scale. So, I can plot sound pressure level in two ways; in first way I can plot here and on the y axis I plot decibels. So, let say it is; suppose the sound pressure level is fixed, suppose the sound pressure level is constant at all frequencies. So, they are generating a sound which when I measure it through microphone at all frequencies the sound pressure level is same; suppose that is one case.

So, this is our engineering scale and that is in decibels, but then lot of times what we are interested in not how much the microphone is sensing but how annoying or how is it being perceived by human beings. So, we plot the sound pressure level on perceived scales. So, this is 0 decibels. So it is 0 decibels here, and let say this is 1000 hertz. Then on the perceived scale it is like this. And on the perceived scale we do not call it decibels, but because these dB's are weighted we say it dB A. So, it is written as dB and in parenthesis it is written as A. So, that is what dB A scale.

So, that is important to understand. So, we can record sound and dB's but then if we want to depict it in terms of perception we have to use the dB A scale. So, it is not written a lot of times people write as dB A, but this is wrong. The correct way to write it is dB parenthesis A. Where, A represents the A – weighting. If we had to do it in on B scale if we had to do it on B scale then we would have written as dB in parenthesis B and so and so forth.

So, that concludes our discussion for today, and we will meet tomorrow. And tomorrow and day after tomorrow we will continue our discussion on perception of sound. And specifically tomorrow we will discuss the notion of loudness which is different than sound pressure level. So, that is all for today and we will meet once again tomorrow. Bye.