Fundamentals of Acoustics
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Lecture - 67
Octave Band Analysis - Part I

Hello, welcome to Fundamentals of Acoustics. Today is the start of the last week of this course; that is the 12th week and over this week, we will cover couple of topics. The first important topic which we are going to cover is octave band analysis and this is a technique which is very frequently used to represent data on noise in the industry. So, that is one thing we planned to talk about. The second theme would be reverb time or reverberation time and finally, we will talk about a couple of additional terminology is a specifically STC that is the Sound Transmission Coefficient, and NRC which is the Noise Reduction Coefficient and both these terminology is are very frequently used in contexts and situations where the intent is to reduce noise getting transmitted from a point a to point b.

Those are the some of the important themes for this week's discussion. And we will start our discussion by talking about octave band analysis.

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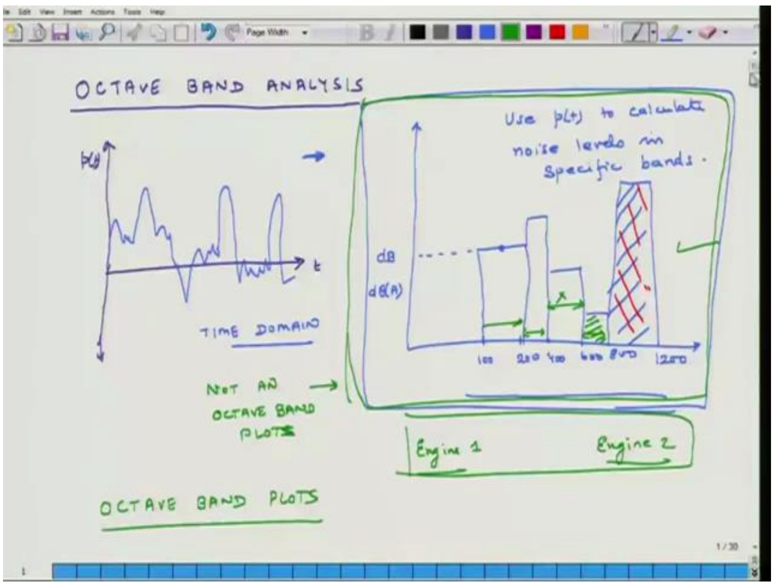

So, first thing what we would like to know is what do we plan to do in this analysis? What do we do? So, consider a noise source, let us say there is an engine in a room and it is generating some noise. So, if I record its signal in time. So, this is time axis and this is pressure as a function of time then the noise signal may look something like this, like this, some noise signals right. Now if you show this noise signal to industry experts, they will not make it, it does not make a lot of sense because they cannot interpret these data. So, essentially you have a large number of points A and each point is a plot of pressure against time.

What do you make of it? So, lot of times industry people in industry and also even in the scientific community, they say that from this data which is in time domain. So, this is in time domain p is, tell us how much sound is being produced in a specific bands. So the question is use pressure in the time domain data to calculate noise levels in a specific band. So, what is a band? Band is a range of frequencies. So, for instance, a person may ask that how much noise is being produced between 100 and 200 hertz. So, you can say that based on this pressure data you will be expected to calculate how much noise is being produced in 100, 200, 200 band. So, that will be 1 number, that will be 1 number and here the units will be either dB or it could be even dB A. So, then they will say I want noise level in 100 to 200 hertz band, 200 to 400 hertz band, 400 to 600 hertz band and so on and so forth. So, this may be 400, this may be 600, this may be 800, this may be 1200.

Here I am not following any specific pattern, but the question which may be asked from you from your employer or from the industry is that if I give you data in the time domain, can you tell me in decibels how much noise is there in each specific band? How much sound energy or sound power is there in each a specific band? So, between 100 and 200 hertz, how much is the sound power level between 200 to 400, between 400 to 600, 600 to a? So these types of plots are very frequently used and people, noise experts look at these plots and then they figure out most of the noise when they look at this plot, they say most of the noise is in this 800 to 1200 band. So, based on this analysis then they say that if I have to reduce noise of this engine, I have to make sure that I reduce this type of noise in the beginning because if I reduce this noise, it will not make much of a difference because the decibel level of noise in 600 to 800 hertz band is very less. So, if reduce or even eliminate 600 to 800 hertz band noise, it will not make much difference to the overall noise level. So, based on these type plots, people figure out strategies to reduce noise in areas or from machines. So, that is one use of these types of plots.

The other use of these types of plots is that they can compare. So, let us say there are 2 engines. So, we have engine 1 and engine 2 and they want to compare how noisy is each of the engine. So, once again the interest is not only to just look at one single number, but they will make a plot like this for engine 1 and similar plot like this for engine 2 and then they will compare that in this particular band 100 to 200 hertz band engine 1 has more noise engine 2 has less noise, in 200 to 400 hertz band engine, 2 has more noise, engine 1 has less noise. So, based on these plots data is interpreted and noise levels for different machines or similar machines are compared. So, then based on that you can make an assessment, this particular machine is better in terms of noise production compared to machine from some other company or something like that.

So, 2 option, 2 important uses, one is these plots help us reduce or develop the strategies to reduce the noise from machines and another important use is that these type of plots also help us compare different sources of noise and then read the different sources in noise in a particular order. So, these types of plots are very frequently used and this is what if you are an expert in noise, this is what is expected of you as a noise engineer to produce plots like these.

Now, there is a special type of plots of this type and they are known as octave band plots. So, this is not a this plot which I have drawn here, it is not an octave band plot, it is not an octave band plot why because this is an octave here, the ratio is 2, but the next band, this is also an octave 200 to 400, but 400 to 600 is not an octave, 600 to 800 is not an octave, 800 to 1200 is not an octave. So, an octave band plots, we make similar graphs, but we plot for noise energy for an octave band which is 1 octave wide. So, the range of frequencies, upper frequency limit and the lower frequency limit in each band is 2. So, these are known as octave band plots and then further you can have an octave band plot like this.

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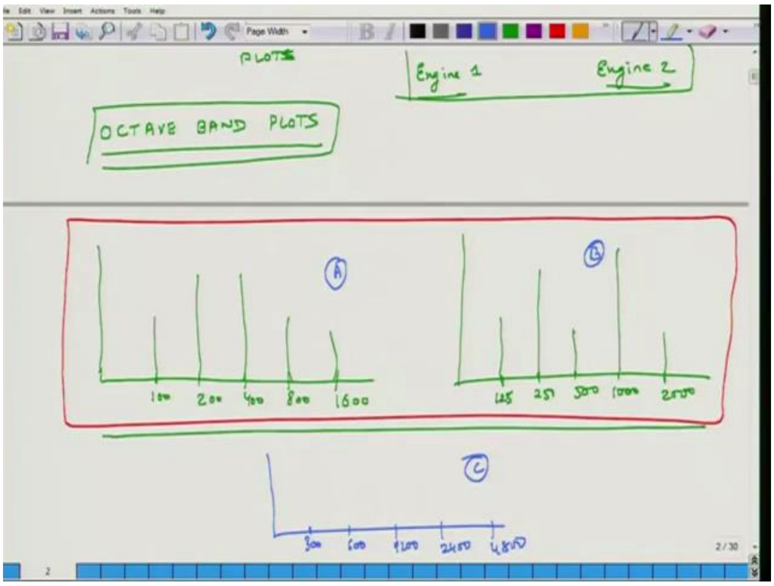

So, let us say, this is 1 hertz, 2 hertz, 4 hertz, 8 hertz, and 16 hertz or let us say 100, 200, 400, 800 and 1600. This is an octave band plot and then for each band plot, you can have different noise levels, another possible octave band plot could be 125, 255, 100, 1000 2000, this is another octave band plot because here also the frequencies at which we are plotting noise are separated by an octave. So, the ratio is 2, but the industry says that I want you to produce these graphs in some both of them are octave band plots, both of them are octave band plots, but the industry says that I want you to produce these plots at some specific frequencies.

In some specific bands because a third person can produce another octave band plot and it could be something like this, 300, 600, 1200, 2400, 4800, this is also if you make plot of or these values it will be an octave band plot. So, amongst all these 3 situations, A B and C, the frequencies at which data is being plotted they are not consistent. So, the industry and experts in Acoustics has said that whenever we are going to report data on noise, we are going to report data on some internationally accepted octave bands. So that you can compel apples with apples otherwise 1 industry or 1 company will produce data in format C, another company making similar devices will produce in format A as you cannot compare those 2. With that intent people have developed standard octave bands.

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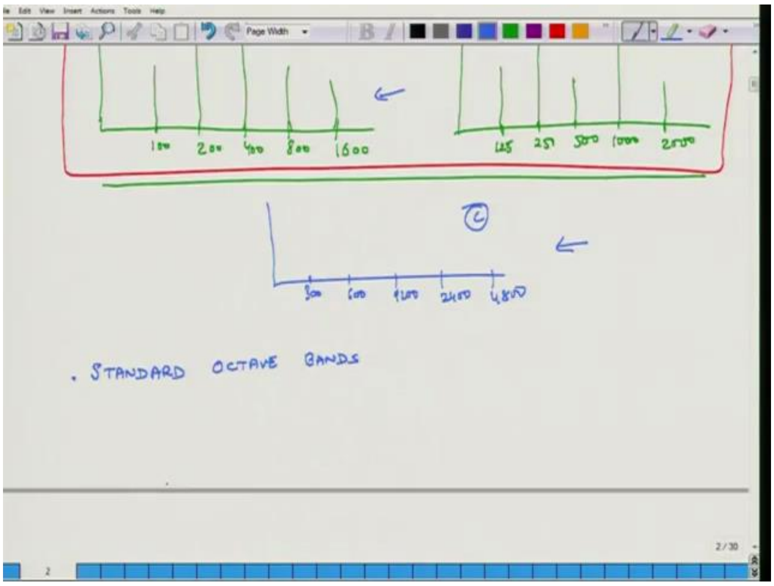

Once again we will go back to our original goal war, what is our original goal? Our goal; our original goal is to learn.

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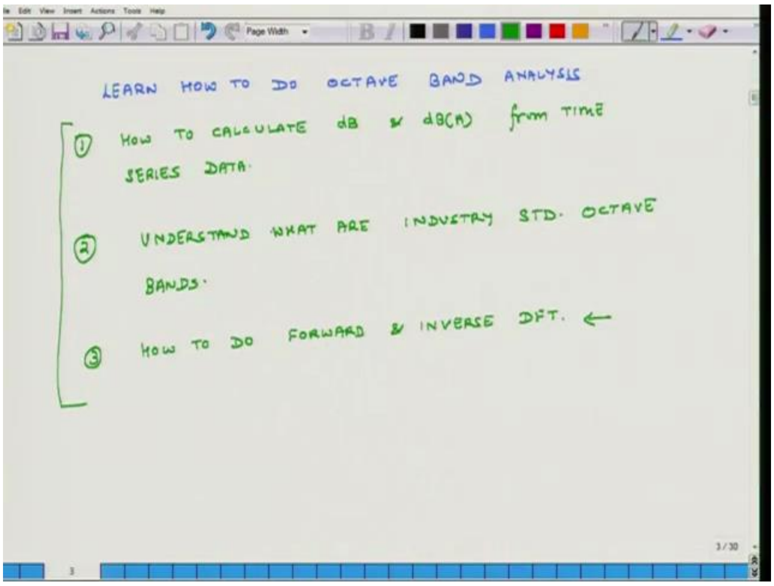

How to do octave band analysis? This is our original goal and to do this we need to know 3 important things, we need to know 3 important things, first we have to know how to calculate dB and dB A from time series data, this is the first thing we have to know, I think we know this to a certain extent, but today we will make it more express it.

The second thing we have to know is understand what are industry standard octave bands and the third thing we have to know is how to do forward and inverse discrete Fourier transform. So, we know these things, we can combine all these information and learn how to do this octave band analysis. So, what we will do is we will address this question first how to do forward and inverse DFT because from there all because once we do 3 then from 3 we can also do 2 we can also do one easily.

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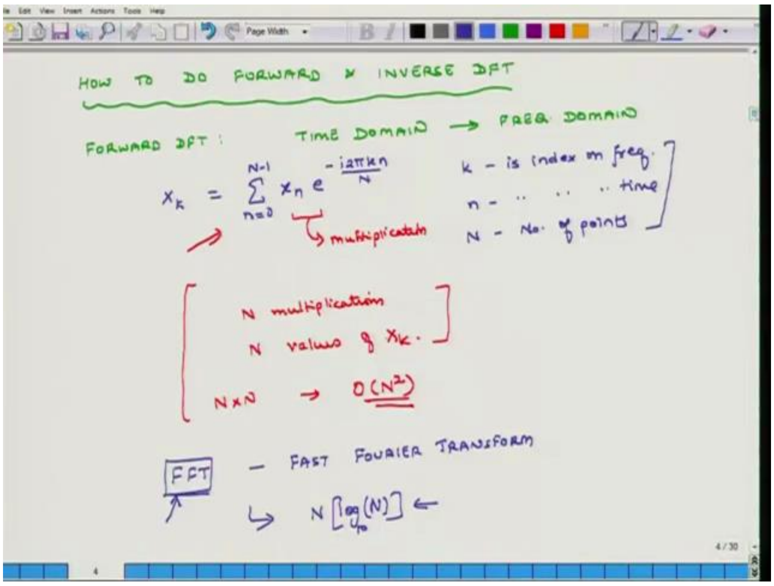

Next couple of minutes, we will discuss how to do forward and inverse discrete Fourier transform, this we had already discussed earlier. So, if there is data. So, what is forward DFT here? We convert data in time domain to frequency domain and the relation for this we have discussed earlier. So, I am just going to sight it, but I will not explain it. So, the relation to do this is this thing. So, here the addition is on the index N and it goes to N minus 1.

Once again very quickly I will recap K is the index on frequency, n is the index on time and N is number of points. So, if we use this transform we can calculate X K, capital X K. So, capital X K is a string of numbers which represents a time series data in the frequency domain, now I will spend may be 2 more minutes on this because I am going to introduce 1 more term. So, let us look at this parameter, what do we see here? Here X N is been multiplied by exponent to the power of I 2 pi K N over N. So, this involves multiplication, it involves multiplication for a given value of K, how many times we are going to multiply it for a given. So, for a given value of K, we are going to have N multiplications, the other thing is and how many times we will have to compute X K N. There are N values of X K; we have to compute for each value of X K, we have to do n multiplications. So, we have to compute N values of X K. So, total number of multiplications which is required to be done is n times N or it is the order of N square. So, the total number of computations which we have to do in the forward DFT is of the order of N square.

If N is let us say 300000, sometimes these time data can be very large numbers or 3 lakhs, then it has to be 300000 times 3000. So, it is a very large number. So, it can take a lot of time. So, this way of doing forward this discrete Fourier transform may not be. So, this is mathematically accurate, but it may not be fast enough. So, some people have developed faster methods to do all these computation. So, special type of DFT is known as FFT and what is FFT? It is known as fast Fourier transform and it is not any different from DFT, it is a particular type of FFT, but it is just faster and in this algorithm, the number of computations which have to be done is N log N, this is to the power of 10. So this number of computations is significantly smaller, it is significantly smaller. So, this is fast Fourier transform and there are several algorithms for this. So, 1algorithm is Cooley Turkey, another is offered by (Refer Time: 20:32) another algorithm is known as prime factor algorithm and there are so on and so forth.

What the point is that in literature, you will most of the times 99 percent of the times you will hear this term FFT and you will not here DFT. So, you may get confused, but please realize that FFT is just a special and a faster version of DFT. So, once you know FFT or DFT, you can convert time data into frequency domain and then for the inverse transformation.

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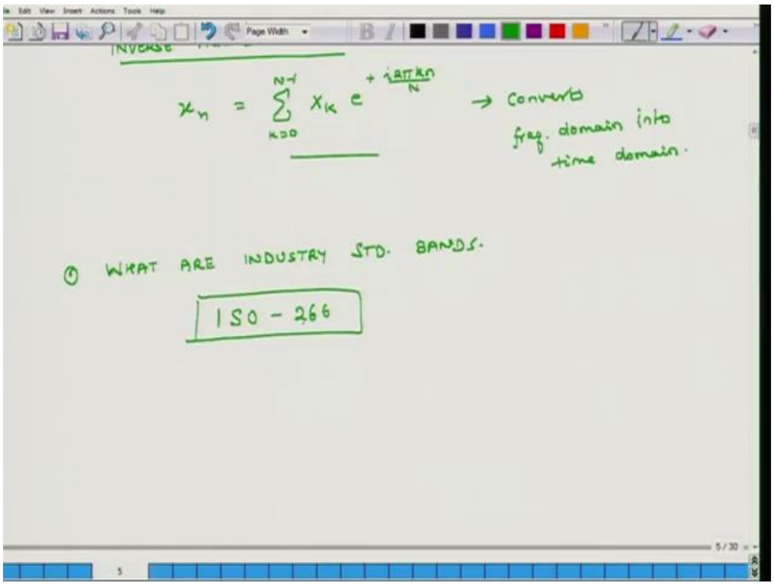

For the inverse transformation, what we do the relation is simple, it is very similar. So, X N is data n time domain and that equals X K E and earlier we had a negative exponent here, we have positive I 2 pi K N over N and here we are adding up these terms on which index K is equal to 0 to N minus 1. So, when I do all the addition K goes away, I am only and I only end up with X N. So, in the first calculation, I compute X 0, in second calculation I compute X 1 and so on and so forth till n becomes equal to N minus 1. So, this gives us, what does this do? It converts frequency domain data into time domain, we converts frequency domain data into time domain.

This is there. So, the point is that if I have time domain data, I can convert it into frequency domain data and you can, I can use the same data or if I want I can modify it and convert it back into time domain data. So, that addresses our first question, how to do forward and inverse transformation? So, the next thing we are going to discuss is understand what are industry standard octave bands? So, once we do these then we will address the third question. So, our next theme is going to be what are industry standard bands and there is actually an international standard for these bands and it is known as ISO, International Standards Organization and 266. So, if you want to learn in detail about these industry standard bands, you should refer to this standard ISO 266 and it gives you all the details of the standard and, but in this course we will still cover some of the details of this standard and we will explain how do we arrive at these band number B band different bands.

That discussion, we will do tomorrow because our time for today's lecture is over and till then have a great day and we will meet once again tomorrow to discuss industry standard bands.

Thank you.