Fundamentals of Acoustics

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Lecture - 68
Octave Band Analysis - Part II

Hello, welcome to Fundamentals of Acoustics. Today is the second day of the last week of this course and what we plan to do today is have a detailed discussion on industry standard band. So, we will talk about octave bands.

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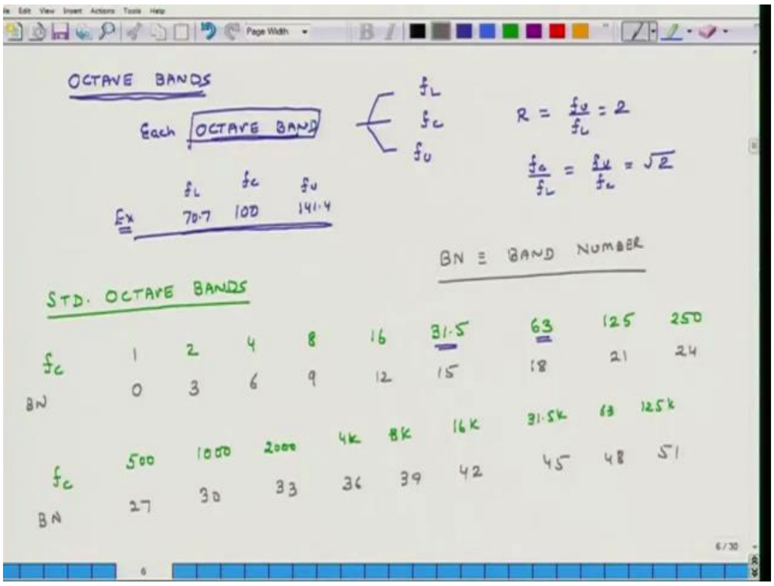

First I am going to list the some of the standard bands and then we will have a discussion on those. So, each band I will say each octave band, each octave band has 3 important frequencies, the first important frequency is known as f L that is the lower frequency limit of the band then it has an upper frequency limit f u and it has a central frequency limit. Each octave band because it is an octave band. So, this is not true for all types of band, but because for octave bands the ratio of f u and f L is 2 and the other thing is, this is one and also the ratio f c divided by f L is same as f u divided by f c. So, which means that this ratio has to be square root of 2 only then we will get f u divided f L are 2.

So, for instance every band has a central frequency, an upper frequency and a lower frequency. For instance example there is a band who central. So, if I know the central frequency of a band, let us say the central frequency is 100 hertz. So, this is f c then if the band is of octave and if the band is 1 octave wide then its lower frequency will be what? 70.700 divided by 1.414 that is its lower frequency limit and its upper frequency will be 141.4. So, whenever we are talking about octave bands their ratio of upper and lower frequency is 2 and the central frequency is located at a distance square root of 2 times away from the lower frequency limit and whenever in industry when we make those plots which I have talked about we report the data for all the band only at the central frequency. So, we add up all the energies f of all the frequencies present in the band and we report it at a single point which is at central frequency.

First what we will do? So, with this understanding what I will do is will I am just going to write some industry octave bands standard octave bands standard octave bands. So, what I am going to write is only their central frequencies because the moment I tell what is their central frequency, I have already defined the upper and lower frequency limit. So, the first band has a central frequency 1, the next band central frequency will be 2. So, central frequency keeps on getting double because it is octave band 4, 4th is 8 then I have 16 then 31.5. So, from 16, I just do not go to 31 or 32, I rather go to 31.5 because we will see it becomes a little convenient mathematically. So, the next one is 63 and then the next 1 should be 126, but we do not use 126 rather we say 125 then next 1 is 250 and in the next row. So, after 250 it becomes 500 and then 1000 then 2000, 4k, 8k, 16k and so on and so forth and then keeps on going.

From 16k, I go to which frequency? 31.5k not 32000 then I go to 63k then I go to 125k and so on and so forth. So, the reasons we do these adjustments slight adjustments here. That we end up with 1000 that is one because then things become cyclic now. So, these are the central frequencies of different octave bands. So, if I am to I have to calculate the upper and lower frequency limits for 2000 hertz band then its upper frequency limit will be 2000 times.

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1.414 And its lower frequency will be 2000 divided by 1.414 and the ratio of upper and lower will still remain 2. Now each band is identified by a band number and what is this band number. So, first I will just write down these band numbers and then we learn where are they coming from? So, the band number for this first band is 0, for this band is 3, 6, 9, 12, 15, 18, 21, 24 and band number for these guys is 27, 30, 33, 36, 39, 42, 45, 48, 51, and so on and so forth. So, these are band numbers. So, B N is band number if. So, I can specify an octave band either by its central frequency or just by stating its band number and we will also learn in next 5-10 minutes that using the band number also I can compute central frequency or the central frequency as well as the lower and upper frequency limits, we will see that. But for the moment just understand the fact that each octave band has a central frequency and each octave band has a band number and if we specify either the central frequency or the band number, I can calculate the upper and the lower frequency limits for the entire band this is there.

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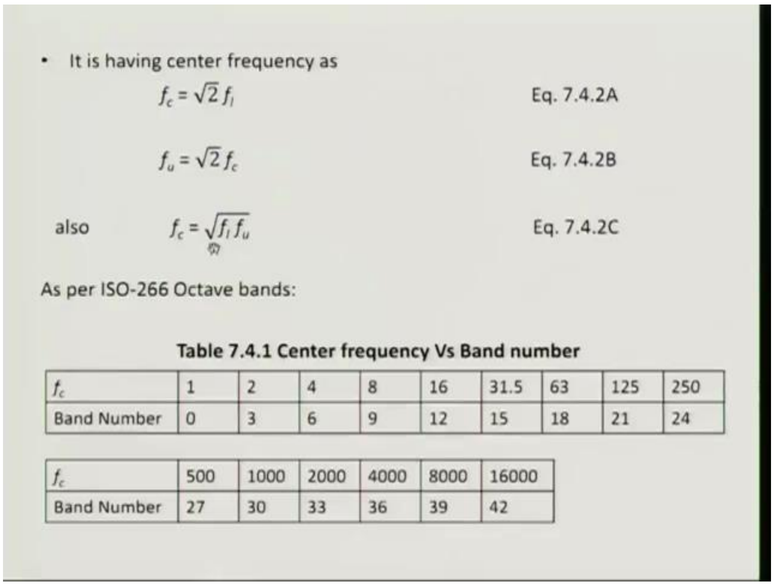

What you are seeing on the screen. So, just very quickly recap what we have discussed is that there is for each octave band there is a central frequency there is a upper frequency and there is also this lower frequency f L and these are the mathematical relations between central frequency upper frequency and lower frequency and as per ISO 1, ISO this standard these are different octave bands starting from 1 hertz going up to 16000 hertz, these are the industry standard octave bands. So, central frequency 1, central frequency 2 and so on and so forth, it goes up to 16000 hertz. So, in total industry standard octave bands between 1 and 16000 are 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 octave bands with their central frequency is starting from one going up to 16000 hertz, now and each band is associated with a band number.

Now, let us consider the band from 200. So, let us consider a band and this is frequency and let us say, this is the 250 hertz. So, 250 hertz is the central frequency and it will have a lower frequency limit. So, this value will be 250 divided by square root of 2. So, actually let us make it a little wider. So that we can, this is the lower frequency limit and this is the upper frequency limit. So, this is f u. So, let us consider this band. So, band number 30, let us plot its central frequency, this is the central frequency, let us call this is 1000 hertz, it has also an upper frequency. So, that will be that times 1.414. So that is 1414 hertz and then it will have lower frequency limit 707 roughly, all the frequencies lying between these 2 limits correspond to the band number 30 this has to be understood. So, band is not from 1000 to 2000 hertz, the band is from 707 to 1414 hertz. Similarly the next band number 33 will be from 1400 to 14 to 2828 hertz. So, this is one important thing to understand that the band is not from 1000 to 2000 hertz band, is from 707 to 14 of 14 hertz with the central frequency 1000 hertz, this is one thing.

The other thing to notice that lot of times people say that these bands are very wide especially as frequency goes up these bands are very wide. So, there lot of frequencies within each band. So, they said the that they are not interested in getting the results for octave bands, but they want the result in one-third octave bands in one-third octave bands. So, in one-third octave band, you take an octave band and break it up into 3 smaller bands. So, this entire range could be broken into 3 smaller range. So, it could be broken into band. So, the overall band is 707 to 1404, but this could be the first smaller band, this could be the second smaller band and this could be the third smaller band. So, if you break an octave band into 3 parts, then it is called the one-third octave band it is called the one-third octave band now for an octave band the ratio of upper and the lower frequency is 2 in one-third octave band the ratio of upper frequency limit and lower frequency limit is 2 to the power of 1 by 3 because if you multiply 2 to the power of 1 by 3, 3 times each you get a ratio of 2.

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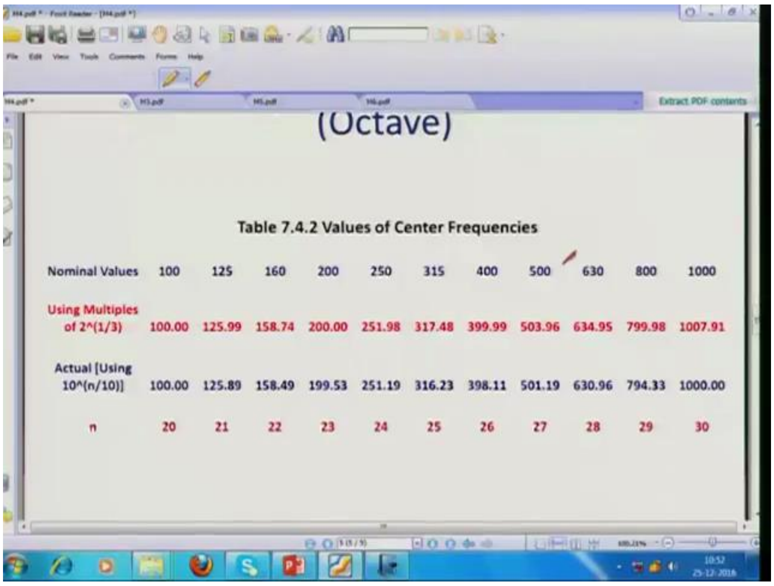

With that intent, this is the table which has been which is shown here. So, you first look at the top line. So, it says nominal values, it forgets nominal values, let us look at the red line here. So, we start with 100 hertz, we multiply it by 2 to the power of 1 by 3, we get 125.99. So, this is 100 is the first central frequency for a one-third octave band, the next octave band has a central frequency of 125.99 then you multiply it again by 2 to the power of 1 by 3 you get 158. So, its central frequency one-third octave band central frequency is 158.0. So, just focus on this line, do not look at other lines, you will get confused and so the next band, one-third octave band has a central frequency 200, 250, 1.98 and so on and so forth, but because these numbers are not easy to remember people have rounded them off to convenient numbers. So, 100 is of course 100, 125.99 becomes 125, 158.74 becomes 160, 200, 250, 315, 400, 500, 630, 800 and 1000.

But there is an interesting observation. So, you can get these central frequencies for one-third octave bands by this relation, but there is another approx another way you can get those. So, this is one way, but this is not the way which is used. So, the way which is used is you take 10 to the power of n divided by 10 and n is the band number. So, n is band number. So, remember what was the band number for let us say 30 band number was 30 for 1000 hertz central frequency, we put the same band number here, but each time you go up by one third octave band, you increase the band number, you increase the band number. So starting from 100, 100 band numbers is 20, 21, 22, 23, it goes up to 30. So, what is the corresponding central frequency is for each band number for 20? It is ten to the power of 20 divided ten square 100. This is 10 to the power of 2.1. This is 10 to the power of 2.2. 10 to the power of 2.3, so, what you see is that these numbers are fairly close; a fairly close.

You can actually use these because in engineering a lot of times we are also practical we are not mathematically precise to 6 place of decimal. So, this is the convenient number and using this approach each time the band number increases by 10, we go from 100 to 1000 hertz, but also if I go from 20 to 23, the ratio of frequency goes up by 2, if I go from 20 to 23, ratio frequency goes up by 2 and this is 1, these are one-third octave bands right then from 23 to 26 again I go up by a factor 2 from 26 to 29, I again go up by a factor of 2. So, 794, it is a little of, but I rounded to 800. So, these are the actual values these are the things. So, so this is what? So, what I am trying to say is that there are octave bands and in this case here ratio is 2 and then there are one-third octave bands. So, 1 there one-third octave bands one-third octave bands and here the ratio is 2 to the power of 1 by 3.

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Table 7.4.3 Third-Octave and Octave Passbands

Band No.	Nominal center frequency (Hz)	1/3 Octave Passbands (Hz)	Octave Passbands (Hz)	Band No.	Nominal center frequency (Hz)	1/3 Octave Passbands (Hz)	Octave Passbands (Hz)
1	1.25	1.12-1.41		11	12.5	11.2-14.1	
2	1.6	1.41-1.78		12	16	14.1-17.8	11.2-22.4
3	2	1.78-2.24	1.41-2.82	13	20	17.8-22.4	
4	2.5	2.24-2.82		14	25	22.4-28.2	
5	3.15	2.82-3.55		15	31.5	28.2-35.5	22.4-44.7
6	4	3.55-4.47	2.82-5.62	16	40	35.5-44.7	
7	5	4.47-5.62		17	50	44.7-56.2	
8	6.3	5.62-7.08		18	63	56.2-70.8	44.7-89.1
9	8	7.08-8.91	5.62-11.2	19	80	70.8-89.1	
10	10	8.91-11.2		20	100	89.1-112	

With that understanding, let us look at this table. So, what it shows is both octave bands and also one-third octave bands. So, we will look at band number 1, it is nominal central frequency. How do we calculate it? We calculate it using this relation 10 to the power of n by 10. So, the moment you know a band number, you use this formula 2 to the power of n by 10 and you get its central frequency and then if you have to compute its lower frequency you divide it by a factor of 2 to the power of 1 by 3 and if you have to compute its. So, these from 1, this is octave, one-third octave band. So, this is higher frequency limit is 1.25 times cube root of 2, you get 1.41 then band number 2 central frequency is 1.6. How do you get it? 10 to the power of 2 by 10, its lower frequency limit 1.6 divided by cube root of 2 upper frequency limit 1.6 times cube root of 2.

Then the third band 2 is 2 and how do you get it? 10 to the power of 3 by 10, lower frequency limit 2 divided by cube root of 2, higher frequency limit 2 times cube root of 2 then you go to 4 and between 1 and 4 how many octave bands have passed? 3. So, each time you go up by 3 octave bands their frequency doubles. So, here 1.25, this is 2.5 understood. So, this is there. So, the point is that are a standard octave bands correspond to central frequency 1 or band number 0, 3, 6, 9, 12 and so on and so forth and you get the same thing. Here this is one industry octave band where the central frequency is 2, 2 to 4 to 8, 16 and here you make an approximation and so on and so forth. So, what this table and this methodology tells you is that the moment you know and octave band, its band number you can compute its central frequency and upper frequency limit higher frequency limit and using this factor of 2 to the power of 1 by 3, you can construct all the one-third octave bands and also octave bands using this method. So, this is. So, we go up to 22.4 kilo hertz and if you want we can go even further. So, this is an important method and using this people have created industry standard octave bands and they are listed in ISO 266.

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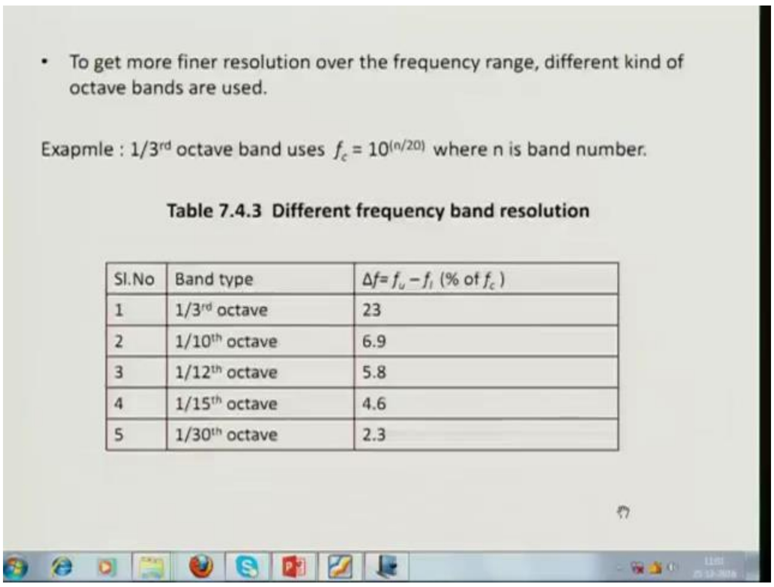

Sl.No	Band type	$\Delta f = f_u - f_l$ (% of f_c)
1	1/3rd octave	23
2	1/10th octave	6.9
3	1/12th octave	5.8
4	1/15th octave	4.6
5	1/30th octave	2.3

There are other types of OC bands also. So, we have already discussed one-third octave bands, but there are other types of bands also. So, there is a one-tenth octave band here, an octave with defined or divided into 10 individual smaller bands. So, in that case, what will be the ratio? The ratio that R, R will be 2 to the power of 1 by 10, if you want to use 1 12th octave band, it will be R will be 2 to the power of 1 over 12 and so on and so forth. So, using that mathematics, if you want to use these, a special fancy bands octave band and one-third octave bands are pretty industry standard, but these are a little more fancy 1 over 10, 1 over 12, one-fifteenth, one-thirtieth, sometimes we will use one-eighth octave bands, one-twenty fourth octave bands. So, if you have those special requirements using this approach you can construct those other octave bands also, but this is the way and the thinking behind developing these industry standard bands.

With this we conclude our discussion for today in terms of how do we go around defining bands and in the next class we will actually learn how do we do octave and analysis which is, what we have started, we started this discussion with. So, that is very much for today and we will meet tomorrow.

Thank you.