Basics of Noise and Its Measurements
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Lecture – 05
Some Key Terms

Welcome to Basic of Noise and its Measurements. My name is Nachiketa Tiwari, this is week 1 and what you are going to listen to is the fifth lecture of this week. Today, what we are going to talk about are some of the principle terms, some of the key terminology which is used in the area of acoustics and noise and its measurements. So, let us look at some of these terms. So, what we will talk about are all of these terms.

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Decibels, Octaves, Decades, Bandwidth, Wave-number, Tones, Noise, and noise is of two types; Pink noise and White noise and then Weighting I have put it here, but probably I will not talk about it today, we will definitely cover weighting, but it will happen may be a little later in the course. But decibels, octaves, decades, bandwidth, wave-number, tones, pink noise, white noise, these are some of the terms which will definitely learn in terms of what they mean in today's lecture.

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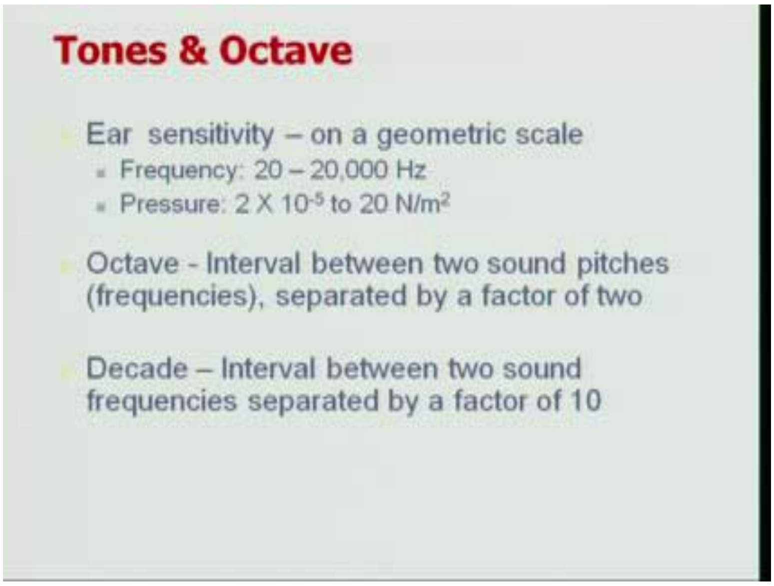

Tones; what is a Tone? When I say 500 hertz tone what it means is that I have generated sound wave, the shape of the sound wave along if I plot the pressure as a function of time is a sinusoidal function. So, tone is a sinusoidally shaped pressure wave as a function of time.

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If I say that it is a 500 hertz sine wave then it means that. 500 hertz tone. It means that pressure is nothing, but some amplitude sin 2 pi f t plus some phase and this value is 500 hertz, so for that reason this is known as a 500 hertz tone. I can have 500 hertz tone, 20000 hertz tone, 1000 hertz tone and whatever. So that is what, a tone is.

The next term is an Octave. What is an octave? So octave is the interval between 2 sound pitches or 2 tones which are separated by a factor of 2. So what is that mean? You have an octave, so I can say 20 to 40 hertz, this is an octave. Why is it an octave? Because the ratio of this 40 over 20 is 2 so that is why it is an octave. Now, why do we actually call it is something octave, o c t because, typically o c t correspond to the notion of 8, that we will see later. Suppose, there is a band in which sound is being produced and there is an upper limit of that band there is a lower limit of the band, and if the ratio of these two frequencies is 2 then it is an octave.

Another example of an octave; 40 to 80 hertz, another example of an octave; 80 to 160 hertz, another example of an octave; 22.5 to 45 hertz. As long as this f 2 and f 1, if the ratio of the f 2 over f 1 is equal to 2, then that band of a sound is known as an octave. Similarly, this terminology is used based on because of some historic reasons. But once the SI system came in to picture then people also introduced a term known as Decade. Some examples have decades; 2 to 20 hertz. F 1 is equal to or 10 f 1 is equal to f 2. This is f 2 this is f 1 so 2 to 20 hertz. Another example of decade; 20 to 200 hertz, this is again a decade. So, all the frequencies lying in between 20 to 200 hertz belong to this particular decade 20 to 200 hertz decade.

In case of an octave, the ratio of upper frequency limit a lower frequency limit is 2, in case of a decade the ratio is 10. In most of the engineering literature octaves are more popular compare to decade, but a regardless when we plot the frequencies on a logarithmic scale either we plot on the x axis octaves or we plot on the x axis decades. The only difference between these two is the ratio of 2 frequencies; upper and lower band widths a lower limits of band. So that is what a tone is and that is what an octave is.

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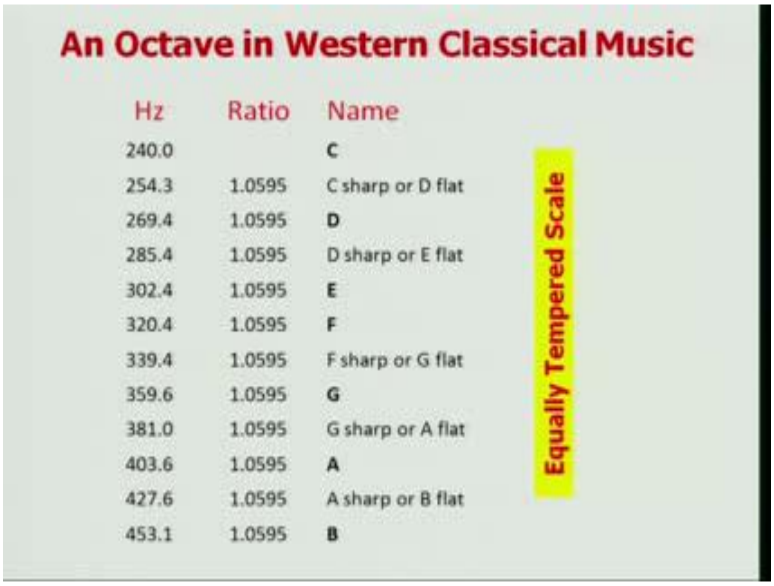

Now, I wanted to give you a historic prospective as to where this number comes from. So, in Western classical music and in Indian classical music we have the seven notes. In Hindustani classical or Carnatic classical music, we have the sa re ga ma pa dha ni sa you know. So, sa re ga ma pa dha ni these are seven notes and then you go to the next level and that is sa again, so there are eight notes, total of eight notes when the cycle of the whole thing starts again. Similarly in Western classical music, you start with c d e f g a b. So, these are seven notes and then you go to the eighth note and then again you start with another c or another sa. Because, the eighth note starts with another sa that is why this entire, and the ratio of the lower sa in this case, let say it is 240 hertz and then we keep on going down and then the next sa which comes or next c which comes is 480 hertz.

So, because the ratio of these 2 frequencies historically was set at two, both on the Indian side as well as on the Western side so that is why it was known as octave. So, octave was a band of you know a frequency band width in which the upper limit and the lower limit was two, but they were eight notes in between. So, that is what is the historic prospective. In octave, in Western classical music and an octave in Indian classical music the ratio of the frequencies was two, but there was seven intermediate notes and the eight note was again a reputation but in the next octave.

Now, in that context I also wanted to bring to you a notice some information about intermediate frequencies. And first we will look at the Western classical system and then we will go the Indian classical system. In Western classical system you start with note c which corresponds to sa in Hindustani, then you go to d which corresponds to sa re re in Indian system, then you go to e which corresponds to ga and so on and so forth. If you look at the ratio of the frequencies here, and then between c and d you have a c sharp or a d flat, between d and e you have d sharp or an e flat, and then between e and f you do not have intermediate frequency, but between f and g you have a f sharp or a g flat and so on and so forth.

Then when you look at the ratios of adjacent frequencies is between c and c sharp it is 1.0595 between c sharp and d it is again 1.0595 and so on and so forth. And, if you multiply all these factors 1.0595 ones to three you know we multiply these by itself the required number of times essentially you will get a factor of 2, and that factor of 2 corresponds to the ratio of frequency of the lower c and the higher c. And because these ratios are constant and they are set at 1.0595, this scale of notes which is used in western classical music which stands over c d e f g a b and then starts with another c this scale of notes is known as Equally Tempered Scale because these notes are in geometric progression and their frequencies get multiplied by 1.0595 successively. So that is what an octave means in a Western classical music and that is how we have borrowed that term octave in to scientific language. The next thing we look at is the Indian classical music.

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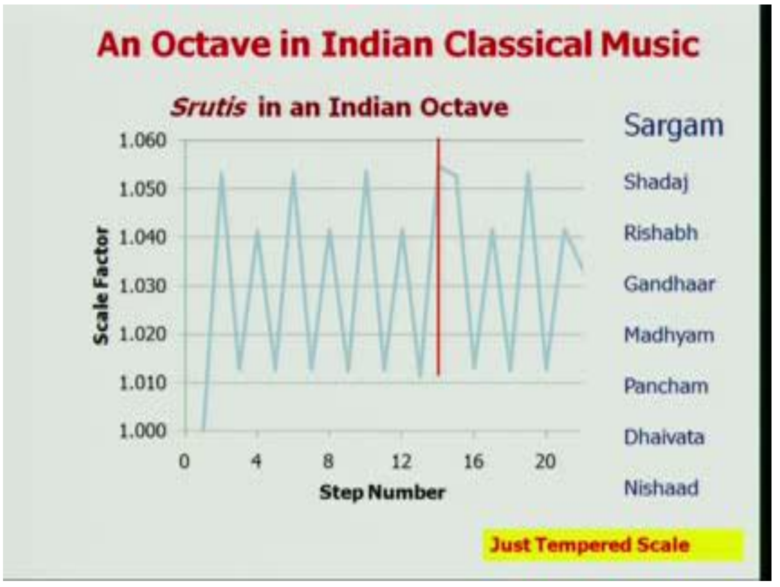

And in Indian classical music, these notes are known as Srutis and the whole scale is known as Sargam. So, the basic note is known as sa and sa is an abbreviation for this note called Shadaj, then you have re which is abbreviation for Rishabh, then we have ga which is Gandhar, ma; Madhyam, pa; Pancham, dha; Dhaivata, ni; Nishaad, and then you have the next sa which is in the next level. Now, in Western classical music these ratios were set at 1.0595 and they were also intermediate frequencies. C sharp or d flat d sharp or v flat e sharp or g flat and so on and so forth.

Similarly, between shadaj and rishabh they are in intermediate frequencies, rishabh and gandhar there are intermediate frequencies and so on and so forth. So that is that much is similar between how notes are organized in Western and Indian classical systems. But a key difference between these two systems is that in Indian classical system the ratio of frequency of the lower sa and the higher sa is 2, but the ratio between adjacent frequencies is not set at 1.0595, but it is set at a level which is most pleasing to the ear. So, in Western classical music you have ratios which are 1.0595 and they are determined mathematically, but there is no reason why they have to sound good or bad, but they are mathematically determined because that is how they figured it out.

But in Indian system, they did not use a rigid mathematical formula for going to success frequencies, but they said that all the intermediate frequencies will be tuning them at specific values such that they sound most pleasant to our ears. So that is how they figure out all the intermediate frequencies, but they made sure that between one sa and the next level sa the ratio was preserved at 2. Because this particular scale the on the Indian side it does justice to our ears it is known as just tempered scale and the western classical music is known as equally tempered scale because the ratios of adjacent frequencies are equal. So, you have a just tempered scale in case of Indian music and equally tempered scale in case of Western classical music.

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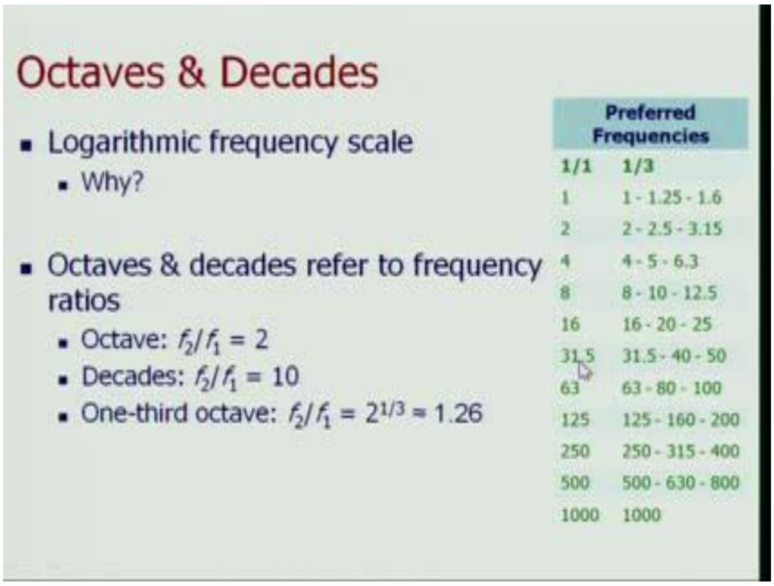

So that is what, I wanted to talk about octaves and decades. Now, it just turns out that theoretically I can have one particular frequency and just two times it that will be an octave. So, I can have 1 hertz to 2 hertz that is an octave and also it could be a 1.5 hertz to 3 hertz that is also an octave. But then when we report literature, when we report results in standard formats typically we use some standard octaves. So, for those standard octaves there are some preferred frequencies and those are written down here. Those frequencies are 1 to 2 that is an octave. So we start with 1, we go to 2, then 4, then eight, then 16 and then when we do not go to 32 but rather we go to 31.5, and then double of that is again 63, then double of that is 126 but we got 125, because you want to end up with 1000. So, there is slight variation in the choice of frequencies then 63 to 125, 250, 500 and 1000.

That is how we have a preferred set of frequencies, and typically we use these frequencies when we are reporting data on logarithmic scales. Then there is also something known as a one third octave band. In case of one third octave band the ratio of f 2 to f 1 is not 2, but 2 to the power of 1 over 3 which is 1.26 and in that case the one third octave frequencies are again tabulated here and they start with 1.25, 1.25, 1.6 and so on and so forth. These are the octave bands which we talk about. Then we have bandwidth.

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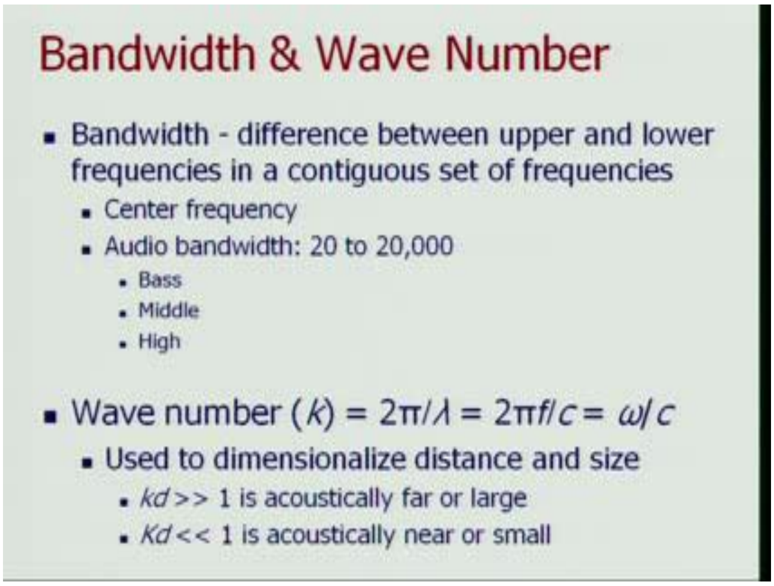

What is the bandwidth? It is the difference between upper and lower frequencies in a contiguous set of frequencies. You have f 1 to f 2, so that your band is f 2 minus f 1 each band has a center frequency and then the audio band width is 20 to 20000 hertz. And a lot times we use these three terms bass, middle and high or treble and they allude to whether the frequency we are discussing about is low frequency, middle frequency or higher frequency. Another term which we will come across rapid frequently will be wave-number which is nothing but 2 pi over lambda where lambda is the wave length of the sound wave, and since lambda equals c over f. Where, c is the velocity of sound and f is the frequency. So, wave number is 2 pi f over c or omega which is angular frequency divided by velocity of sound.

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We have already talked about tones and noise tones, but then there is another type of sound which is frequently used is in engineering literature and it is known as noise. What is noise? It is essentially a sound which has all sorts of frequencies mixed up in to it. And a lot of times we actually define, what is the content of each frequency when we are defining noise? So we can have different types of noise. We can have a type of noise known as white noise and in white noise what we have is that we have equal power within a fix band width for any center frequency.

Then there is another type of noise known as pink noise, and here the power is spectral density is inversely proportional to the frequency or alternatively you can also say that there was equal power in each octave and we will see. This is also known as 1 over f noise and we will see some more details about it.

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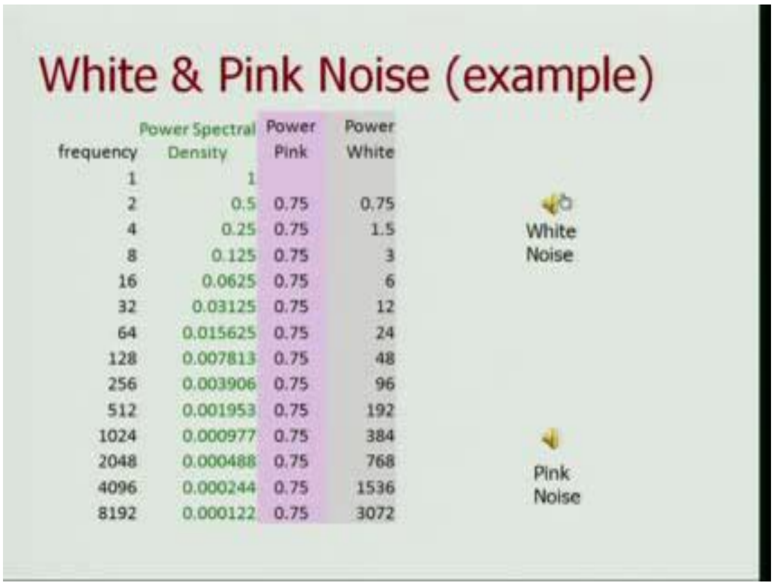

Here is a table which talks about pink noise and white noise. So, the pink column is corresponding to pink noise and the white gray column corresponds to white noise. Now let us look at this table carefully. So, what you see is that when you have this pink power, so from 1 to 2 hertz band the total power in that band is 0.75 hertz for pink noise. Then 2 to 4 hertz again it is a 1 octave white band the power is still 0.75. Each time you go up to an octave the total power in that particular band remains at 0.75 hertz, but when you have white noise then it does not happen like that you start with 0.7 then you go to the next band your power actually goes up by a factor of 2 so it is 1.5. Then you go to the next octave 4 to 8 hertz your power goes to 3, then you go to 8 to 16 hertz again that is an octave but a power it keeps and going up by a factor of 2.

So, what that means is that in pink noise you have per octave the energy content is same, but in white noise you have per octave the energy content keeps and going up as you go up on the frequency scale. What I will do here is actually play both these types of noise so that you can get a feel of how this sound like. So this is what white noise sounds like. I will play it again. This is white noise, and this is pink noise. So, this is how these two different types of noises sound like, you can interpret a this a in a way that pink noise is a little more gentle and if you look at it is spectrum we will talk about this later also it is closer to real music. But, white noise is a little harsher and not that pleasing or appealing to our ears. So, that I think brings to the closure of this module this particular lecture.

Thank you very much for listening to it and look forward to see you tomorrow.