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Introduction to Sound Level Meters and Measurement Parameters

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ABSTRACT

This is the first of a series of papers tasked with providing a tutorial for the measurement of sound levels. As an introduction we will discuss the physical properties of sound, and some of the key parameters for assessing sound level. In the context of this paper I touch on many of the parameters but leave it to some of the other contributions in the group of papers to expound upon.

1 INTRODUCTION

Sound is such a common part of everyday life that we rarely take the time to appreciate its complexity and value. Sound provides enjoyable experiences such as listening to music or to the singing of birds. Sound enables spoken communication with family and friends. Sound can alert or warn us — for example with the ringing of a telephone, or a wailing siren. Sound also permits humans to make quality evaluations and diagnoses — the chattering valves of a car, an out of tune piano, or a heart murmur. The Sound Level Meter is the tool for measuring sound.

1.1 Human Hearing

The human perception of sound begins before we are born, and is the second of or senses, after touch, to begin being processed by our developing brains. Relative to vision, which has about a million nerve fibers, per eye, the ear has relatively few, about 15000 hair cells in each cochlea. Amazingly, human hearing covers the range of three decades (1000:1 ratio) of frequency span, where the eye only spans a 2:1 frequency range for sensing electromagnetic radiation.

The majority of the "sound processing" that humans perform on is done with the brain. The brain looks for patterns in the firing of the auditory nerves, and directs us to react in reflex, triggered on frequency content and arrival times between the ears, or in a more analytical sense, relating the sound to the other observations, and memory. The whole process is called "Hearing", or perhaps, "Listening".

1.2 Sound as a physical parameter

Sound itself is the physical property of pressure variations in the air. For the ear to sense the sound, those variations need to be above 20 cycles per second, and below 20000 cycles per second. We use the unit Hertz (abv. Hz) to describe the frequencies of sound. For a healthly, young human the threshold of hearing ranges from an RMS value of 15 micropascals (at about 3.5 kHz) to about

50kPa at about 20 Hz. By the time the pressure averages about 1 Pascal it is getting pretty loud, and at 50 Pascals we will be covering our ears.

This wide range of amplitude response is over a million to one ratio. In acoustics it is common to use a logarithmic power ratio to specify sound levels – the Decibel.

$$Lp = 10 \times Log({}^{p^2}\!/_{p_o^2}) \quad \text{where } p_0 = 20\mu\text{Pa} \tag{1}$$

20 microPascals is about the threshold of human hearing at 1000Hz. The range of human hearing is from about 0dB to 140dB. Sustained or repetitive levels over 135dB peak and over 115 dB RMS will cause hearing damage. Recommended average level limits for an eight hour workday is just 85dB (A-weighted).

1.3 Creating Sound

There are three common ways to create the pressure variations that make sound: vibration, flow, and explosion. Each has its own properties that can be used to diagnose (either by the brain, or measurement instrumentation) the source of the sound. Those properties have temporal (time based) or tonal (frequency based) signal characteristics.

While creating sound can be the goal of an apparatus, such as a loudspeaker, musical instrument or the human voice, most often, the sound produced be a device is a byproduct of the forces or processes used in that device. In these cases, the unwanted sound is called "noise". Commonly, an alternative name for a sound level meter is "Noise Meter".

2 THE SOUND LEVEL METER

The sound level meter is a tool that makes no aspirations to try to "hear". Instead it is a tool to assess various <mostly> standardized parameters of sound pressure variations in air. In doing so, with a qualified and calibrated instrument, the levels provided are governed within a certain tolerance, or more precisely, precision. This precision and test methods are specified in IEC Standard 61672. Each certified SLM must make available the published results of the IEC61672 test.

2.1 Minimum Requirements

At a bare minimum, a sound level meter needs to calculate the RMS decibel equivalent sound pressure level with specified temporal (Fast or Slow) and a frequency based weighting of "A". The A-Weighting filter approximately follows the inverse 60 Phon equal loudness contour provide in ISO 226 (2003). The output of signal of a microphone with a flat response, using A-Weighting allows the sound level meter to measure like a human hears. 60dB(A) is approximately the level of normal human speech at 1 meter's distance.

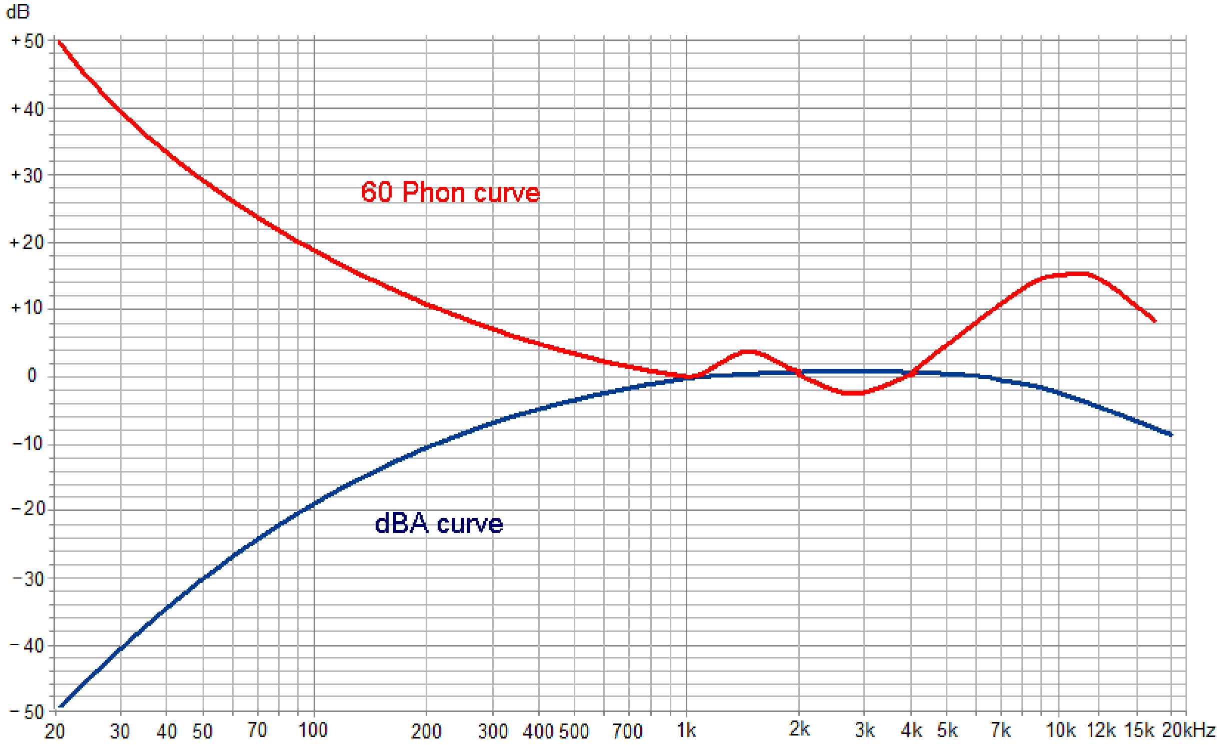

Figure 1: A-Weighting and 60 Phon Equal Loudness

An IEC61672 Class 1 certified instrument (Class 2 certified instrumentation is allowed to be less precise) also should include a "C" Weighting Filter with optionally a "Z" "Unweighted" filter. The C-weighted filter is essentially "Flat" with high pass and low pass filters at the frequency extremes of human hearing. Sometimes an intermediate "B" filter is also specified. An unfiltered "Z" weighted measurement will measure to frequency extremes of the instrumentation, and, its response will vary from SLM to SLM based on the microphone and signal processing limitations.

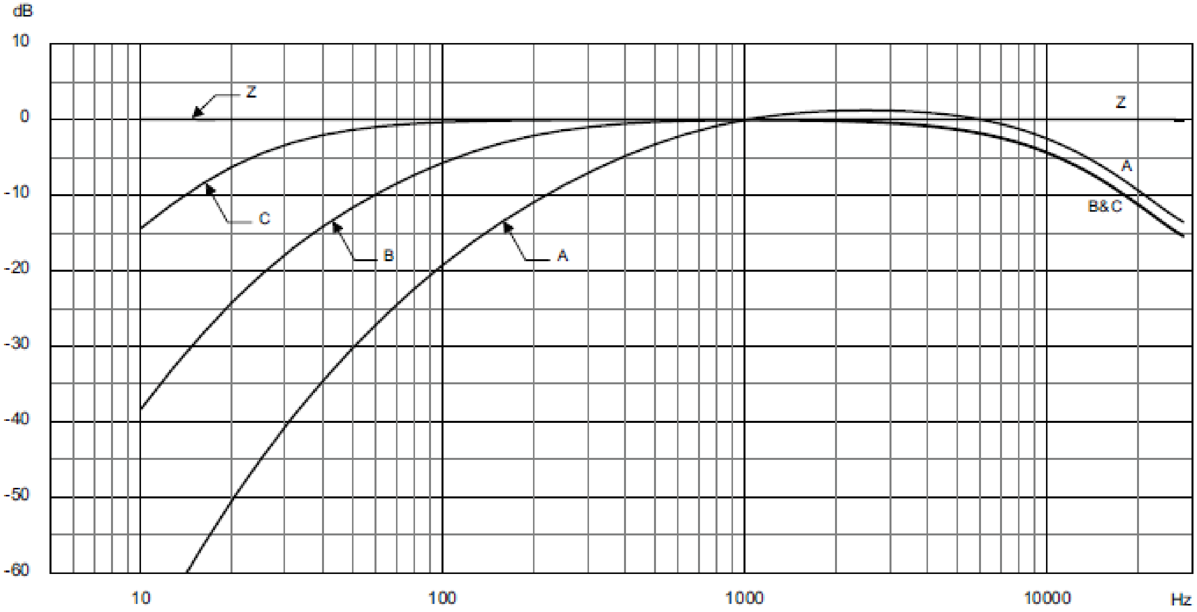

Figure 2: Frequency Weighting Filter shapes (A, B, C & Z) from 10Hz to 25.6kHz (Brüel & Kjær Type 2245)

2.2 The Microphone

Virtually all sound level meters use a condenser microphone, with diameters from a nominal ¼-inch to ½-inch diameter. These diameters allow measurements up to and beyond the 20kHz frequency limits of human hearing. The condenser microphone covers a fairly wide amplitude range, with noise floors, including associated electronics, approaching the lower levels of human hearing and extending to above the "threshold of pain" of 140dB peaks pressure. Specifications do vary, as does the high frequency "tuning" of the microphone to optimize the response from free-field to diffuse-field maximally flat response.

The microphone attached to a sound level meter is generally omnidirectional, until the frequency rises so that the wavelength of the sound starts being significant relative to the dimensions of the sound meter. The electrical signal from the microphone and its electronics is typically range adjusted and digitally sampled in modern instrumentation.

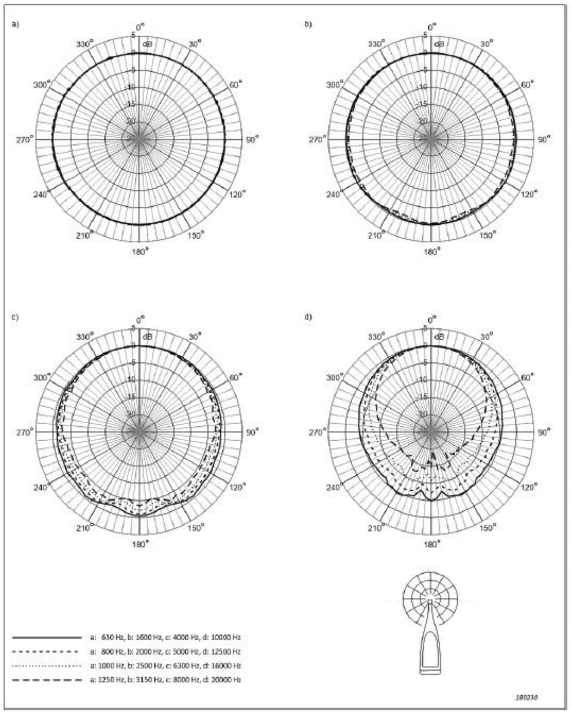

Figure 3: IEC 61672 Pattern Definition of the 2245 Sound Level Meter

2.3 Temporal Response

The instrumentation sampling rate and the frequency weighting processing determine optimum response time in the instrument. The positive or negative maximum swings of the stored signal determine the peak response time of the meter. The eardrum responds to peak pressures, and this parameter (PeakMax) is often assessed for hearing conservation. However, the human signal sound processor, our auditory nerves and brain, is a little too slow to respond and perceive those peak signals.

2.3.1 FAST Response

The sound level meter assesses the level of the sound using an RMS (Root Mean Square) algorithm. The RMS level is proportional to the energy content of the signal. The RMS algorithm is sound level meters is specified in the standard to have an exponential averaging time of FAST or SLOW. The names go back to the days of needle based instrumentation in the days of yore. The FAST weighting corresponds closely to the apparent perceived loudness of the signal – with an averaging time of ¼ second. It takes ¼ second for the signal to respond to within 97% of it's true amplitude. The Standard VU meter in recording electronics uses a similar 300 millisecond averaging time to get to 99% of true amplitude. The electrical time constant (63%) of the FAST response setting is specified as 125 milliseconds. Common parameters we assess are FAST Maximum, FAST Minimum. On a sound level meter the parameter might be displayed as:

LAFMax 67.3dB

L for Level in dB

A for "A" weighted frequency

F for FAST response time
Max for the highest value in the measurement period.

Because the A-weighted FAST response corresponds somewhat to the perceived loudness, we also complile or “sample” the measured level. From that array of results we can calculate statistical values, LN, where N is a percentage of time exceeded. For example, a parameter of LAF90 provides a value of the FAST “Averager” that was exceeded 90% of the measurement time. This value is often used as an estimate of the “Background” noise levels. The LN parameter is not governed by standards and the “sampling” rate of the FAST RMS level varies from instrument to instrument, though it is usually at least 10 samples per second to minimize statistical uncertainty.

2.3.2 Cumulative Statistics

Because the A-weighted FAST response corresponds somewhat to the perceived loudness, we also compile or “sample” the measured level and create a statistical representation of the sound level. In the sound level meter these are listed as the generic parameter, LN, where N is a percentage of time exceeded. For example, a parameter of LAF90 provides a value of the FAST “Averager” that was exceeded 90% of the measurement time. This value is often used as an estimate of the “Background” noise levels.

LAF90 37.5dB

Other commonly specified LN values:

LAF5	The sound level exceeded 5% of the time. A better representation of an “apparent maximum” level
LAF8.3	For an hour long period – this represents the sound level exceeded for a total of 5 minutes.
LAF10	Occasionally used instead of LAeq (see below) for environmental noise limits
LAF50	The median noise level – half the time above and half the time below
LAF95	Often used as background noise levels in place of LAF90. Either parameter can be used as an indicator of environmental impact – as well.

The LN parameter is not governed by standards and the “sampling” rate of the FAST RMS level varies from instrument to instrument, though it is usually at least 10 samples per second to minimize statistical uncertainty.

2.3.3 Slow Response

The SLOW RMS average setting is eight times the FAST setting. It takes two seconds for the SLOW Response to reach 97% of its sound pressure accuracy. When the FAST level is fluctuating greatly – say more than 5dB – You can switch to “Slow” to get a better idea of the “average” of the fluctuating level. The SLOW weighting shows up now and then in regulations, noise ordinances and other specification. As with FAST, the Typical SLOW response parameters are SLOW Maximum and SLOW Minimum. Because SLOW is not proportional to human perception of loudness you do not often see “SLOW” based statistics.

Note: With a steady signal longer that last more than a couple seconds (as with a calibration tone) the FAST and SLOW values will be identical. With signals that fluctuate the FAST Response will have a wider Max-Min spread than the SLOW Response

2.4 Equivalent Level (Leq)

What if we were monitoring highway traffic noise. The signal is not steady, and the frequency of events vary with time, the average speed of the vehicles, and even the mix of the type of vehicle. It might not be that interesting to look at the maximum level, LAFMax, as that has little impact in the overall noise exposure to the surrounding area. Instead, we want a long term average of the noise level, perhaps in 15 minute intervals. Here we will use the integrating functionality of the meter, where we assess and update the RMS value instantly with time. This parameter is called the Equivalent Level. That is, a value that contains the same amount of acoustic energy of a steady signal operating over the same length of time.

Note, that because of the logarithmic nature of the decibel, you cannot use arithmetic averaging. A minute at 70 dB followed by a minute at 60dB is not 65dB, but instead is 67.4dB. In fact, a minute at 70 dB and a minute at only 40dB is still 67.0dB for the total 2 minute period of acoustic energy. The Leq, is the go to measurement for most measurements of sound. For product noise or environmental noise, Leq gives you that physical quantity of sound exposure. The Leq of the measurement is usually express like this:

LAeq,60s

L for Level in dB
A for "A" weighted frequency
eq for equivalent level
60s for the measurement time.

If the measurement time is expressed elsewhere the, time T, in LAeq,T may be omitted.
Note that we longer need to specify the RMS exponential weighting, FAST or SLOW. The Leq is a linear average, every moment of signal is considered equally in the calculation.

If the time duration of the measurement is not specified in the measurement requirements, it is easy to look at the Leq value to see when it does not seem to change significantly with increasing time. Some sound level meters include a parameter for "Standard Deviation" for the LAeq measurement to help you gain an understanding of variation relative to the current measurement time. Sound level meters with Leq capability are sometimes referred to as "Integrating Sound Level Meters".

3 SUMMARY

The Sound level Meter is the go to tool for assessing sound pressure level. The standardized specifications assure a confidence is the precision of your measurements. The IEC 61672 standard defines the capabilities and the procedures for evaluating and designing sound level meters. If the

IEC Specification for the sound meter is not publicly published, do not trust the device, as if may only provide conditional performance to the standard.

Selecting the correct measurement parameter as defined in the regulation or procedure is important, and in reciprocal, is important for procedures to define the correct assessment parameter.

4 References

1. Sound Level Meter Type 2245 with Microphone Type 2245, Instruction Manual, https://www.bksv.com/downloads/2245/instruction%20manual/be1910.pdf, November 2019
2. *Electroacoustics — Sound level meters — Part 1: Specifications*, International Standard IEC 61672-1:2013 (International Electrotechnical Commission, Geneva, Switzerland, 2013).