Frequency weightings and responses

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Introduction

The frequency weighting is not where the most dramatic changes are found when comparing present and past sound level meter standards. To see what will happen in the new standard and understand the limitations regarding improvements to the specifications for frequency weightings, it is worthwhile to look shortly at the past historical development and at the present standards IEC 651 and 804 for comparisons with the proposal for IEC 61672.

The past

Frequency weightings were described already in the 1940s in American and German standards. In the American standard, the weighting functions were based approximately upon the inverse of the 40-, 70-, and 100-phon equal-loudness contours valid at that time.

In 1961, IEC issued "Publication 123" - Recommendations for sound level meters. In IEC 123 the frequnncy-weighting functions were slightly modified for the purpose of simple electronic design and it was pointed out that "although the weightings approximate very roughly certain properties of the ear, they are to be considered merely as conventional". This guidance, combined with the requirement that the sound level meter "shall allow measurements to be made with any of the curves, at all sound levels within the range of the apparatus", has led to the present situation that the A-weighting is used universally for measurements of sound level.

This was not the original idea but experience has shown that there is a fair correlation between the impression of noise and the A-weighted sound level. Not bad, considering that the A-weighting was defined for another purpose and modified for simple electronic design (maybe the B-weighting, if chosen, would have led to the same result!). Anyway, the A-weighting is there, it has been unchanged and used for nearly 40 years, and lots of data are available for comparison.

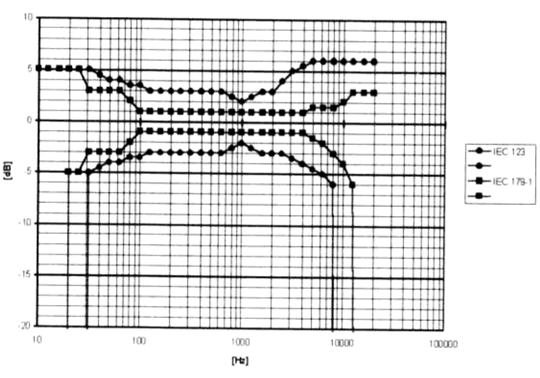

Fig.1 - The original tolerances given in IEC 123 and IEC 179

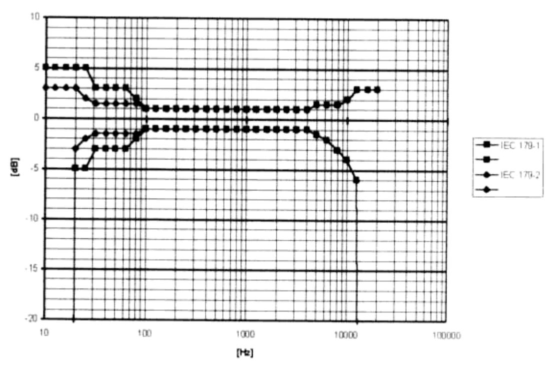

Fig.2 - Improved tolerances from IEC 179

In IEC 123 the tolerance limits were rather wide and in 1965 a new standard was published. In this standard, IEC 179 - Precision sound level meters, the requirements were basically the same as given for IEC 123 but the tolerance limits were narrowed to satisfy the need for the better measurement precision obtainable with the then-current technical state-of-the-art. Fig.1 shows the frequency weighting tolerance limits for IEC 123 and IEC 179.

In 1973 IEC 179 was revised and new tolerance limits for the frequency weightings were introduced implying narrower tolerance limits for the lower frequencies (Fig.2).

In 1979 IEC published a consolidated revision of IEC 123 and 179. The idea was to put both standards into one document and at the same time introduce two new precision classes or types. IEC 123 and 179 were transferred to the new IEC 651 as Type 3 and 1, respectively, with minor changes. A new Type 2 was introduced with the purpose, in time, to replace the use of the outdated IEC 123 based instruments with instruments designed with state-of-the-art techniques. Fig.3 shows tolerance limits for the four precision classes.

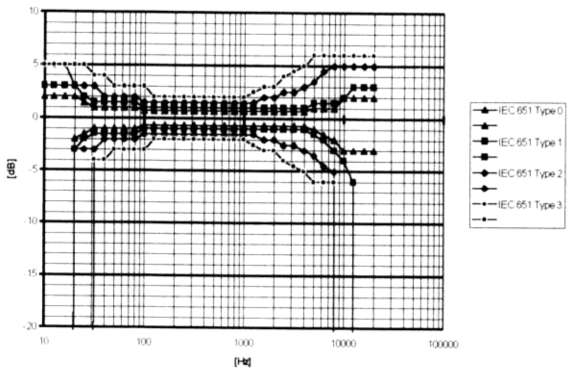

Fig.3 - Frequency weighting tolerances from IEC 651 for Type 0, 1, 2, and 3

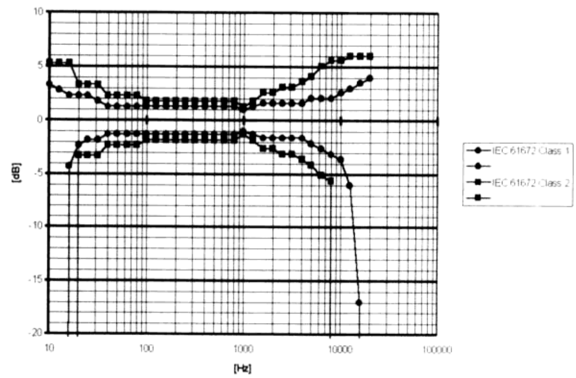

Fig.4 - Frequency weighting tolerances from IEC 61672 for Class 1 and 2

The present

In 1991 IEC/TC 29 started a new working group (WG4) charged with the task of preparing a new sound level meter standard, this time without too many bindings to the existing standard, IEC 651. This new standard IEC 61672 also includes specifications for integrating-averaging sound level meters and therefore is also intended to replace IEC 804. In this standard there are only 2 precision classes 1 and 2. Class 1 is, with respect to frequency weightings, comparable with IEC 651 Type 1 and Class 2 with Type 2.

No precision class is comparable with IEC 651 Type 0 and Type 3. The reason to delete “Type 0” was that there has been nearly no interest for this class, and “Type 3” is deleted because this class is obsolete. Better precision is now obtainable without excessive costs. Fig.4 shows the frequency-weighting tolerance limits for the remaining two precision classes. Compared with IEC 651 two things can be seen as different. First, the tolerance limits are slightly wider, and second that there are finite tolerances down to 16 Hz and up to 16 kHz. The reason for the wider tolerance limits is that the tolerance limits now have to include the maximum measurement uncertainty for testing. The reason for widening the frequency band for finite tolerance limits is a bit more complex.

Even though most common noise phenomena have their dominant spectral components at mid-frequencies, certain phenomena may have strong components at frequencies below 20 Hz or above 12,5 kHz. Looking at fig.4 it is easily seen that the tolerance limits here are extremely wide, from +3 dB or +5 dB to - ∞ . Sounds with strong frequency components may therefore result in very different results when measurements are carried out with sound level meters of different makes and models.

This is of course not desirable. Different possibilities exists to overcome the problem. One possibility is to arrange cut-off filters for frequencies less than 20 Hz and greater than 12,5 kHz. However, if this is going to have any effect, these cut-off filters should always be there. But this would, as a matter of fact, change the design goal for the frequency weightings.

An ISO working group, WG 46, was established to define the change to the design goals. However, it soon became evident that there was a very strong resistance to any change to the frequency-weighting design goals. Another possibility was to design filters for optional use, i.e., if strong low-frequency or high-frequency components were present (and could be readily detected by listening) the filters could be switched in. However, it would then be necessary to design the filters in a way that both situations, filters included and filters not included, were inside the tolerance limits. The reason for the filters was then questionable. Furthermore, a high-frequency cut-off filter was already standardized in IEC 1012 for measurement of audible noise in sound fields with strong ultrasound components. ISO/SC1 WG 46 was closed down after the first meeting!

Another possibility is to require finite, narrow tolerance limits down to 10 Hz and up to 16 kHz or 20 kHz. This is neither easy nor desirable. In the high-frequency end, most microphones designed for sound level meters have a cut-off at some frequency above 8, 12,5 or 16 kHz depending on make and model. To move the cut-off to a frequency above 20 kHz would partly be expensive and partly result in microphones with lower sensitivity. There was strong resistance to this change. To narrow the tolerance limits down to 10 Hz would, technically, be relative simple, but would, for some applications, be very inappropriate because wind noise can be strong in the frequency range below 20 Hz. The dynamic range for outdoor noise monitoring systems would be dramatically reduced if there were no allowance for low frequency cut-off.

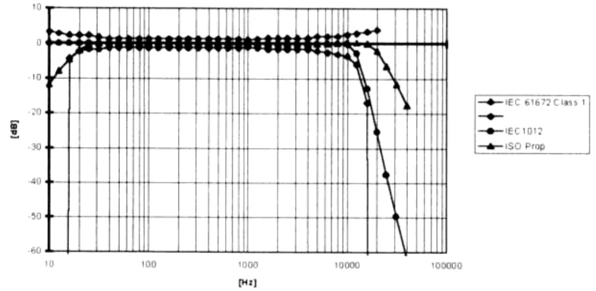

Fig.5 - Proposed cut-off filters and existing HF cut-off filter IEC 1012.

The chosen solution was a compromise that introduced finite tolerance limits down to 16 Hz and up to 16 kHz. Tolerance limits were established allowing for LF cut-off below 16 Hz, and wide enough at 16 kHz that the HF cut-off filter defined in IEC 1012 can still be used. The result is seen in Fig 5.

In the new IEC 61672 the frequency weightings are, as in IEC 651, defined by means of the poles and zero's. Even though not affecting the tabulated values given with

0,1 dB resolution, the pole-zero definition has given rise to severe discussions. The reason for this is that the pole-zero values from IEC 651, given with four significant digits, were not "exact" as intended from the beginning. In IEC 61672 the pole-zero values may be calculated by means of analytical expressions to any precision desired for an application.

The B-weighting is deleted in IEC 61672. No ISO standard refers to B-weighting even though it has existed for nearly 40 years. Therefore the working group found that it was about time for deletion.

The C-weighting remains as is. This "weighting" originally was designed as a flat response with smooth roll-off at the higher and lower frequencies. This frequency weighting is now used for "peak" measurements. Absolute peak sound pressure levels really should be measured without any frequency weighting. However to avoid influence from wind noise, door slams etc., frequency limitations are desireable. Also, to minimize phase distortions the frequency cut-off should be smooth. The C-weighting was a fair choice for the purpose, partly because it has these qualities and partly because it is already there!

A new frequency "weighting" is introduced. Its name is Z-weighting (Z for zero) and it is a frequency response function defined as "flat" in the frequency range defined for A- and C-weightings and using the same tolerance limits.

The future

Better precision and better instruments are always desirable. The requirements to instruments are always compromises between the desired precision and the technical possibilities and costs. The result of the IEC 61672 work is a compromise too and reflects what is possible for now, taking into account the great spread in technical and political interests manifested in a working group with 30 members and regular observers from 19 different countries. However, looking at the standard as a whole it is easy to see that even though the precision is generally improved, there are still tolerances so great that considerable dispersions can be expected from the same measurement situations when instruments of different makes and model are used.

The greatest tolerances are found for the frequency weightings, as mentioned, and for the directional characteristics. For the frequency weightings, large tolerance limits are required and desirable because different applications require different possibilities for frequency limitations. For the directional characteristics because the "ideal" microphone (still) is infinitely small and with perfect spherical sensitivity characteristics. Microphones do have finite sizes resulting in directional characteristics different from the ideal.

A real improvement, with respect to reproducibility between measurements carried out with instruments of different design, is only possible if the requirement for only one specification is dropped and different microphone configurations for different applications are defined. And so for frequency cut-off, making it possible to introduce finite and narrow tolerances for the frequency range of interest and get rid of all outside this. However, this improvement is for the future!