"A-Weighting": Is it the metric you think it is?

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ABSTRACT

It is the generally accepted view that the "A-Weighting" (dBA) curve mimics human hearing to measure relative loudness. However it is not widely appreciated that the "A-Weighting" curve lacks validity especially at low frequencies (below 100 Hz) and for sounds above 60 dB. Research in the field of equal loudness has progressed and redefined the shape of the original 40 phon Munson and Fletcher equal loudness curves. Unfortunately, the "A-Weighting" curve has not been revised in the light of this research or ISO 226. This paper highlights some of the changes in the research and problems identified with "A-Weighting" as it has come into current usage.

INTRODUCTION

The A Weighting was introduced in sound level meters based on the American Tentative Standards for Sound Level Meters Z24.3-1936 for Measurement of Noise and Other Sounds (Cited in Pierre and Maguire 2004). This standard adopted the 40 decibel loudness levels of Fletcher and Munson to establish the "Curve A" (A-Weighting) and 70 decibel for the "Curve B" (B-Weighting). However it should be recognized that over time the usage of the "A-Weighting" has changed from that intended in Z24.3-1936. For example the "A-Weighting" would be used for low to moderate sound levels and the B weighting for the moderate to high sound levels (Marsh 2012, 9).

LOUDNESS

Fletcher and Munson

The experiments in "Equal Loudness" by Fletcher and Munson (1933, Table 1:88) used pure steady tones and the frequencies 62, 125, 250, 500, 2000, 4000, 5650, 8000, 11300 and 16000 hertz (Allen and Neely 1997, 3644). The originally reported study (Munson 1932), using telephone receivers was carried out using eleven frequencies and eleven subjects only, though the Fletcher and Munson (1933, 83) paper had the observer facing the sound source one meter away using both ears.

The testing procedure as reported in the Fletcher and Munson paper was:

> "The observers were seated in a sound-proof booth and were required only to listen and then operate a simple switch. These switches were provided at each position and were arranged so that the operations of one observer could not be seen by another. This was necessary to prevent the judgments of one observer from influencing those of another observer. First they heard the sound being tested, and immediately afterwards the reference tone, each for a period of one second. After a pause of one second this sequence was repeated, and then they were required to estimate whether the reference tone was louder or softer than the other sound and indicate their opinions by operating the switches. The levels were then changed and the procedure repeated." (Appendix A:104).

The published paper smoothed the data from a number of tests and then curve fitted to produce the figures below. There is no information in the paper identifying the method or justification for extrapolation of the curves beyond the test frequency range.

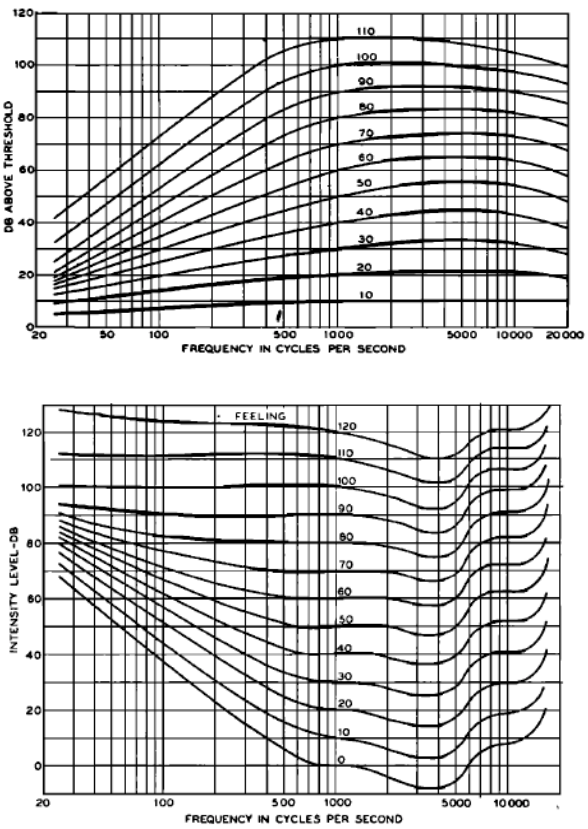

Figure 1 (Fletcher and Munson 1933, 90-91 Figures 3 and 4)

Loudness Standards

Research into loudness has continued with a number of significant studies being published that have shown significant variations (see **Figure 2**) to the "classical equal-loudness contours for pure tones by Munson and Fletcher" (Bauer and Torick 1966, 143). There have been many researchers in the area (Suzuki and Takeshima 2004, 919 Table 1). Early researchers include Churcher and King (1937), Zwicker and Feldtkeller (1955) and Robinson and Dadson (1956).

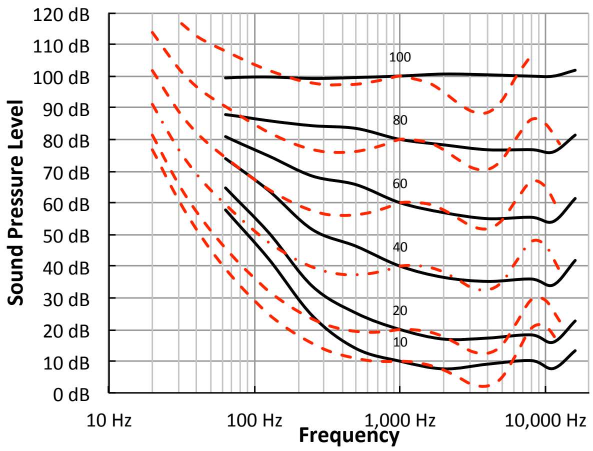

Figure 2 Robinson and Dadson as represented in (*AS 3657.1-1989* pg 7 values from Table 2) (dashed red lines) Equal Loudness compared to the Fletcher and Munson contours (solid line)

The Robinson and Dadson curves were adopted in the ISO/R226, 1961 and ISO 226, 1987 (Suzuki and Takeshima 2004). Suzuki reports that many researchers have found deviations below 800 Hz where the equal loudness levels where higher than those determined by Robinson and Dodd.

The ISO 226, 1987 was further revised in 2003 based on the work of an international research group (AIST 2003). This revision has significant differences (up to 15 dB) in frequencies below 1000 Hz as seen in **Figure 3**.

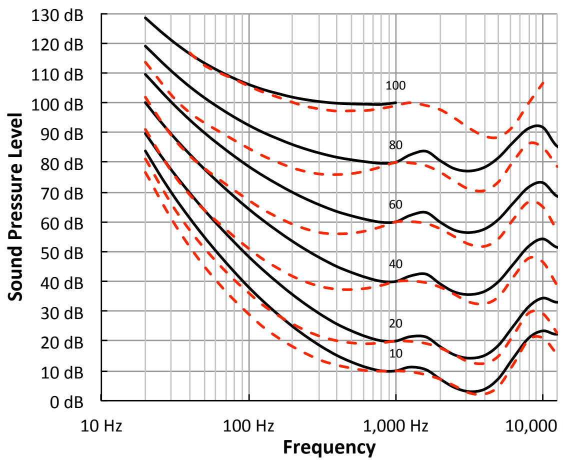

Figure 3 ISO 226 Comparisons: Revised curves in black, dotted red lines show the previous values as represented in (*AS 3657.1-1989* pg 7 values from Table 2)

It is suggested (Measurements in Detail: A-weighting in detail) that the performance of the headphones used in the 1933 Munson and Fletcher experiments would have had poor low frequency response, thus likely that the subjects would have been hearing higher harmonics of the actual frequencies thus providing improved sensitivity at the lower frequency.

FREQUENCY WEIGHTING

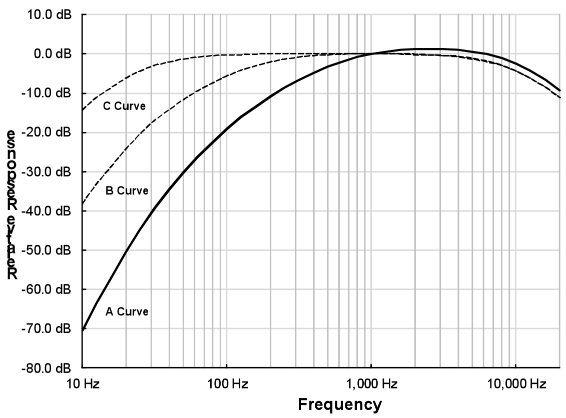

Figure 4 Weight Contours (*AS 1259.1-1990: Sound level meters Part 1: Non-integrating* 1990) and (*AS IEC 61672.1-2004 (IEC 61672.1:2002) Electroacoustics - Sound level meters* 2004)

The "A-Weighting" was first introduced into physical devices with the introduction of the Z24.3 standard in 1936 ("American Tentative Standards for Sound Level Meters Z24.3-1936 For Measurement of Noise and Other Sounds" 1936). This standard defined frequency response as "Curve A" and "Curve B" and "flat response" only three years after Munson and Fletcher published their equal loudness contours. Curve A and Curve B are described as the 40 and 70 decibel equal loudness contours. While not specifically stated in that standard, that the curves are directly taken from Munson and Fletchers work, it is widely recognized that these curves are the 40 and 70 phon Munson and Fletcher equal loudness contours (Berglund, Hassmen, and Job 1996), (Pierre and Maguire 2004), (Suzuki and Takeshima 2004) and (Salomons and Janssen 2011).

In later usage the "Curve A" or 40 decibel came to be labelled as "A-weighting" and later as dBA. Similarly for the "Curve B" or 70 decibel – dBB and later the "C curve" (introduced in Z24.3-1944) 100 decibel – dBC. In common usage the A, B and later C weightings were intended to be used for measurement of sounds of low, medium and high loudness levels (Berglund, Hassmen, and Job 1996, 2989) and (Marsh 2012).

It is reported that in *"1967, agreement was reached in the International Standards Organization (ISO) on the future instead of three rating curves worldwide to only use measuring devices with A-weighting. This allowed a single international registration of noise emissions (equipment out) and pollution (arriving at the ear noise), even if the values obtained corresponded with sine tones and narrow band noises about the actual volume level"* (Sengpiel). It is interesting to note that in the Australian context, the "B-Weighting" was still in the 1990 Australian Standard AS1259.1 (*AS 1259.1-1990: Sound level meters Part 1: Non-integrating* 1990, Withdrawn) yet had been dropped in the 2004 AS IEC 61672.1 (*AS IEC 61672.1-2004 (IEC 61672.1:2002) Electroacoustics - Sound level meters* 2004).

Figure 5 shows the variation between the 1936 'Curve-A' and Equal Loudness research over time.

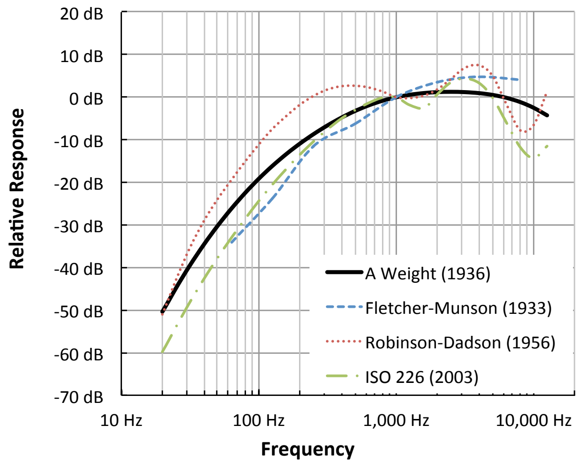

Figure 5 40 Phon Curves and the equivalent dBA curve

Figure 6 illustrates the relative variations between the dBA curve and ISO 226-2003 revised equal loudness curves.

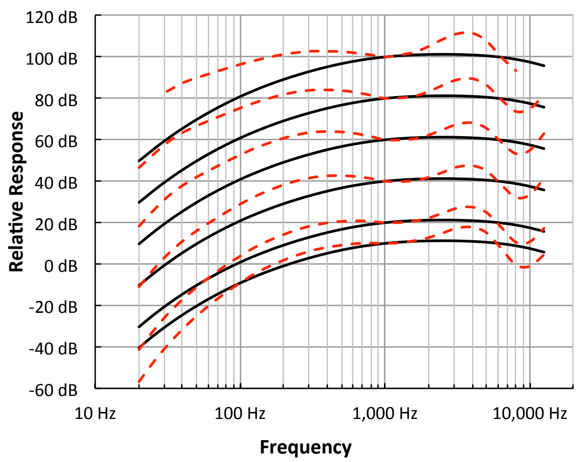

Figure 6 ISO 226-2003 (dashed – red curves) and dBA (solid black curves)

A Weighting

Many authors have identified that the existing “A-Weighting” does not measure loudness particularly well across the wide range of sound and noise events normally reported in terms of “A-Weighted”. For noise exposure/noise control usage, which may be the major usage for marketing purposes, Pierre and Maguire (2004) and others identify some of the problems with “A-Weighting” for loudness measurements:

- It is only representative of hearing at low levels (below 60dB)
- Application of the loudness contours and “A-Weighting” to complex tones, rather than just single tones as used in the Munson and Fletcher experiments.
- Random noise is generally perceived as louder than single tone as used in the Munson and Fletcher experiments.
- Does not take into consideration the spectral shape of the sound.
- Could produce misleading results for noise control applications.
- Minimises the effects of high low frequency sounds.
- The original equal loudness contours (Munson 1932) were based on telephone receivers, few subjects (11) and limited frequencies. Age and gender were not considered as variables in the research as shown to be significant by Robinson and Dadson (1956).
- Under estimates sound below 100 Hz (Berglund, Hassmen, and Job 1996)
- The reduction in consideration of the effects of low frequency noise on hearing loss and threshold shifts (Salomons and Janssen 2011)
- Diminished reliability for sounds over 60 dB (in terms of loudness)
- Repeatability of measured results for typical noises is compromised in that the frequency spectrum is not taking into consideration (Barstow 1940) and (Salomons and Janssen 2011).
- In the public health area annoyance due to tonal components is a significant issue. This is not adequately addressed particularly with low frequency sound, in the “A-Weighting”. An example used by Salomons and Janssen (2011) is the power transformer hum at 50 Hz.

CONCLUSIONS

If it is accepted that the intention of the original Z24.3-1936 standard ("American Tentative Standards for Sound Level Meters Z24.3-1936 For Measurement of Noise and Other Sounds" 1936, 147) was to allow loudness measurements where *“if a given noise of a general character is measured with any meter designed in accordance with the standards, the result will be substantially the same as that which would be obtained with any other similarly designed meter”*, then the validity of the “Curve-A” now known as “A-Weighting” or dBA to measure loudness is an integral component of the definition.

Research by many authors has demonstrated that the original 40 and 70 phon (A and B) curves as implemented in Z24.3 have significant validity issues especially in the low frequency below 100 Hz.

The current “A weighting” does not fulfilled the intent of the original Z24.3-1936 standard to provide a standard method of measuring loudness as many authors have demonstrated.

With the current digital technology it would be feasible for the implementation of the equal loudness curves in line with present research (ISO 226:2003) into redesigned “A-Weighting” filters which would provide industry, acoustic practitioners and the public with better equipment capable of providing more realistic and meaningful measurements. Programming techniques would compress what was a raft of curves (A, B, C, …) into a single easy to use result with the weighting depended on the measured level.

Having measured results as envisaged in the original Z24.4 - 1936 standards based on the full range of loudness measures as suggested above would seriously impact the substantial number of standards, guidelines, product ratings, etc. that have been based on the “A weighting” scheme as it is currently enshrined.

Therefore the existing evolved standard of “A weighting” should be separated from its loudness roots to maintain the relationships with ‘marketing’ and ‘legislature’ usage. This could be relabelled as “a weighting”. The lowercase “a” denotes just another weighting scheme! A new metric is needed to provide the loudness usage as originally envisaged in the 1936 standard.

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