Acoustics Forum

THE 'A' FREQUENCY WEIGHTING

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1. INTRODUCTION

The 'A' frequency weighting is used extensively in many acoustical noise measurements. Although almost exclusively used, it is often misunderstood or incorrectly defined even by those who would be expected to have a better knowledge. It is commonly stated in glossaries, even in official documents or textbooks on acoustics or noise, as *"a scale that simulates the response of the human ear"* or similar erroneous nonsense.

2. ORIGINS OF THE A-WEIGHTING CURVE

The human hearing system is not as sensitive to all sounds if they vary in pitch or frequency. Generally, the low frequency bass tones (i.e. 50 to 250 Hz) sound slightly quieter than the tones in the mid-audio frequency range (i.e. 1 to 4 kHz). Experiments were carried out by Harvey Fletcher [1] at the Bell Telephone Laboratories in New York, in the early 1930s to determine how loud tones of different frequencies sounded subjectively. A series of curves on a graph were drawn from these experimental results. These become flatter in frequency with higher sound pressure levels and are known as equal loudness contours. From these contours, three curves known as A, B, and C frequency weightings were developed for use in sound level meters. These frequency weightings were specified in an American Standard for sound level meters in 1936 [2]. The 'A' frequency weighting is shown in Figure 1, this approximately follows the inverted Fletcher and Munson 40-phon curve (± 3 dB). The 40-phon curve is based on the subjectively reported equal loudness magnitudes at various frequencies relative to 40 dB at 1 kHz.

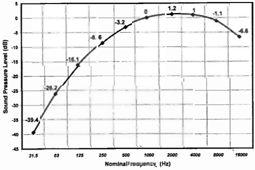

Figure 1. The 'A' Weighted frequency filter relative to 0 dB at 1 kHz.

The symbol for the 'A' frequency weighted sound pressure level, measured in decibels is 'L_{PA}' [3] although the common abbreviation is dBA or dB(A). Either of the two abbreviations could be used but the symbol is preferred as this places the 'A' with the level and not with the decibel, which incorrectly implies there are different types of decibels.

3. LIMITATIONS OF 'A' WEIGHTING

Due to its simplicity and convenience, the 'A' frequency weighting has become popular and it is an often-used frequency weighting for many different noise sources. It is used for all types of noise assessments from occupational noise, building acoustics, loudness assessments and noise annoyance assessments.

The World Health Organization (WHO) [4] has recognised that the 'A' frequency weighting is an overall value which may simulate neither the spectral selectivity of human hearing nor its non-linear relation to sound intensity. Quite wrong and totally misleading statements in glossaries are commonly given for the 'A' frequency weighting such as *"The 'A' frequency weighting adjusts the noise level to the subjective response of the human ear"* or reference is made to *'A-weighted decibels'*, which, of course do not exist and should be expressed as 'A' frequency weighted sound levels in decibels.

Fletcher and Munson derived the original equal loudness curves using only eleven observers who listened to pure tones through headphones. In their paper Fletcher and Munson (1933) stated *"...it would be necessary to increase the size of the group if values more representative of the average normal ear were desired"*.

The equal loudness contours were re-determined under more stringent conditions in 1955 using ninety subjects. The re-determined equal loudness contour curves are similar to the original curves on first impressions but can vary by up to 11 dB in the low frequency (e.g. 100 Hz) range.

Even if the 'A' frequency weighting could be used as a good universal predictor of loudness it is not a good predictor of noise annoyance, particularly for sounds which differ from those which are medium level, broadband mid-audio frequency, and have constant temporal characteristics.

It is often stated that the 'A' frequency weighting follows the 40-phon equal loudness contour. The confusion comes from the fact that there are two sets of equal loudness contours – one from Fletcher and Munson and another from Robinson and Dadson (1956) [5]. The 'A' weighting frequency filter is close to the Fletcher and Munson 40-phon curve but varies by up to 8 dB at low frequencies from the *'more representative'* Robinson and Dadson 40-phon curve. This is a significant difference as it represents close to a 50% change in the perception of subjective loudness. The two 40-phon curves, at the low frequency end of the spectrum are compared to the 'A' frequency weighting in Figure 2.

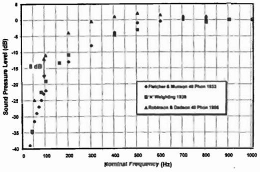

Figure 2. The 'A' Frequency Weighting and the Equal Loudness Contours from Fletcher and Munson and Robinson and Dadson.

Many noise sources in the environment are low frequency. When assessing these noise sources the 'A' weighting frequency filter can be regarded as a high-pass filter with a cut-off frequency (10 dB down point) at about 250 Hz. Hence, where a noise source is dominated by low frequency, the use of the 'A' frequency weighting gives a poor indication of loudness and an abysmal indication of noise annoyance.

Annoyance is multi-dimensional, in fact, at low sound pressure levels the character of the noise (e.g. temporal structure and frequency content) can become, by far, the dominant factor in the annoyance perception. This was clearly shown in research carried out by Scannell [6] where subjects compared a low frequency repetitive impulse noise to pink noise for both loudness and annoyance. Here a character correction of up to 15 dB was found to be required where audible sounds were at a very low sound pressure level but were unpleasant in character.

Scannell found that for annoyance, any penalty added to the objective measurement for a source with unpleasant character must be level dependant with a higher penalty for lower sound pressure levels. The fact that character is more important than the sound pressure level can be realised by considering the simple case of a 'dripping tap' noise when trying to sleep.

The 'A' frequency weighting should be used for occupational noise assessments (except peak noise assessments) because there are *'known'* relationships between the statistical risks of hearing damage and the overall long term 'A' frequency weighted noise exposure level [7].

The 'A' frequency weighting has, unfortunately, never been changed from the 1936 American Standard even though it was based on results where Fletcher and Munson indicated that they were not necessarily representative of the average normal ear. This was later proved to be the case by Robinson and Dadson. Hence the 'A' frequency weighting is not even a rough approximation (i.e. about 50% error) to the response of the human ear at 40-phon.

4. SUMMARY AND CONCLUSIONS

The 'A' frequency weighting is not a scale, it cannot be used to *'establish a human dose response relationship'* and it does not simulate the response of the human ear. The 'A-weighting' should always be described in a glossary as the 'A' frequency weighting to distinguish it from a time weighting. The 'A' frequency weighting must be used for occupational noise assessments but should be utilized with extreme care when an indication of loudness or noise annoyance is required.

A possible improved description of the 'A' frequency weighting is: *the 'A' frequency weighting is used as a rudimentary approximation to the subjective human perception of loudness at low sound pressure levels. There is a known relationship between the statistical risk of occupational hearing damage and the A' frequency weighted exposure to noise. It is however not a good frequency weighting to use when assessing annoyance from noise which is predominantly low frequency (i.e. below about 250 Hz).*

REFERENCES

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