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INAUDIBILITY - WHY IT CAME INTO USE AND AN OBJECTIVE ALTERNATIVE

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INTRODUCTION

Inaudibility, as a criterion for assessing annoyance from amplified music, has been used in Scotland for over 10 years. A survey of all Scottish District Councils [1] found that previous criteria used were based on the Wilson Report [2], BS 4142 [3], ISO 1996 [4] or N R Curves. None of these gave a good correlation with the subjective response of the complainant or the Environmental Health Officer (EHO). Therefore, many Scottish EHO's abandoned their sound level meters and reverted to just listening.

Listening is of course, a valid and vital part of any noise assessment, however, without the addition of an objective appraisal, complications can arise, such as ensuring the same criteria are applied by different assessors and giving guidance to planners.

NOISE FROM AMPLIFIED MUSIC

When modern discotheque music has passed through one or more walls, only the sound within a frequency range of approximately 50Hz to 200Hz, generally remains. This is shown in curve 'a' of figure 1. It is this noise which is the well known source of annoyance.

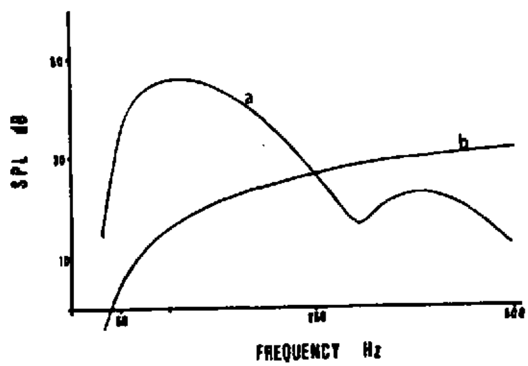

Figure 1(a) The average spectrum of typical amplified music when passed through one or more walls. (b) The 'A' weighted frequency filter at a sound pressure level (SPL) of 35dB.

All previous criteria listed above, have suggested the use of the 'A' weighting frequency filter, which can be regarded as a high pass filter with a cut-off frequency (10dB down point) at 250Hz. The 'A' weighting shows a good correlation with annoyance for most noises because most noises have spectra in the higher frequency range. The good correlation is, therefore, to some degree coincidental [5].

It does seem very odd to attempt to measure a low frequency noise source via a high pass filter. However, is it not the case that the 'A' weighting filter represents human response to noise? Does it not follow the 40 phon curve?

To answer these questions we need to look into the history of the 'A' weighting. It was specified as long ago as 1936 [6] and derived from work by Fletcher and Munson in 1933 [7]. Fletcher and Munson used eleven observers, who listened to pure tones, at a constant temporal rate, through headphones.

The 'A' weighting does indeed, follow the 40 phon curve of Fletcher and Munson. More detailed work into equal loudness was carried out by Robinson and Dadson in 1955 [8] using 90 observers in a free field. This shows a difference at low levels and low frequency of 8dB to 10dB as shown in Table 1. The 'A' weighting is much closer to the 20 phon curve of Robinson and Dadson.

TABLE 1 - A comparison of low level, low frequency equal loudness values (dB).

	Fletcher and Munson		Robinson and Dadson		'A' weighting	
frequency(Hz)	50	100	50	100	50	100
phon						
20	44	32	32	16	30	19
40	32	22	24	11	30	19

Both of these works used pure tones at a constant temporal rate, where amplified music is a complex tone and has a repetitive impulsive temporal structure. To derive the comparative human response to this type of noise source, further research was carried out by Scannell [9] using 18 observers. The interesting result was that the loudness of a low frequency repetitive impulsive noise is perceived to be statistically the same as a continuous, mid-audio frequency pink noise, where the use of the 'A' weighting would predict the latter to be some 15dB louder. The results of the loudness of both noises are shown in one curve in figure 2.

What we are really trying to judge, however, is not the loudness but the annoyance. Is there a difference? One of the main factors affecting the difference between these attributes is the duration. Loudness is not generally affected by duration (after the first 20 milliseconds or so [10]) whereas annoyance will increase with the duration.

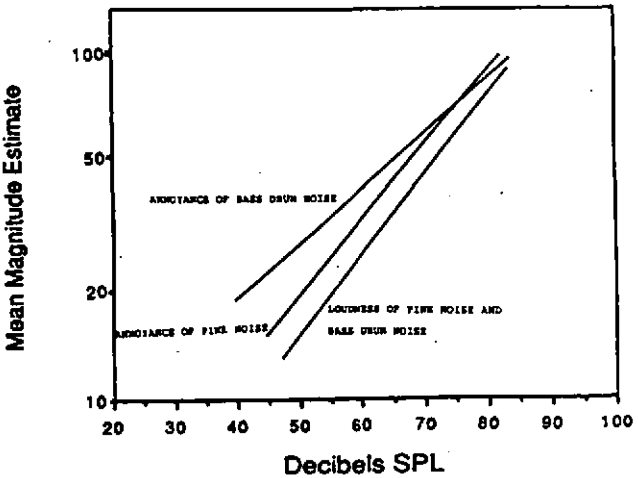

Figure 2 Results of experimental data from Scannell, 1988 [11] showing the loudness of pink noise and the bass drum noise on the lower curve. Annoyance of pink noise is at a higher level (approximately 5dB) and symmetrical to the loudness. Annoyance of bass drum noise is asymmetrical to the loudness and the difference is greater as the pressure levels (SPL) decrease.

To take this into account the observers were asked to judge the annoyance of the noises as if they occured for the whole of the evening within their home.

The results showed some further interesting points. The annoyance value of the pink noise was higher than the loudness (by approximately 5dB) but it was symmetrical with loudness i.e. a constant 5dB over the whole of the measurement range (50dB to 80dB).

The annoyance of the low frequency repetitive impulsive noise (a digitally recorded 'real' bass drum) was asymmetrical with loudness as shown in figure 2. In other words the correction factor is level dependent. This implies that any correction factor used, must increase as the measured sound pressure level decreases.

From these results, a simple model can be found [11] for the equivalent annoyance level (EAL) for amplified music (through walls) which is:

$$EAL = (L_{eq,T} \times 0.7) + 20 \quad \ldots\ldots\ldots\ldots\ldots 1$$

or

$$L_{eq,T} = (EAL - 20) / 0.7 \quad \ldots\ldots\ldots\ldots\ldots 2$$

Where $L_{eq,T}$ is the measured equivalent continuous sound pressure level over the duration T, in this case in the octave bands with 63Hz and 125Hz centre frequencies.

The results will give an equivalent, in terms of annoyance, of amplified music (through walls) to the 'A' weighted sound pressure level for other continuous broad band noises.

ILLUSTRATION FOR PLANNING

The Department of Environment Circular 10/73 [12] gives recommendations for maximum levels of acceptable traffic noise in terms of L_{A10} and factory noise in terms of corrected noise level (CNL). Examples are shown in Table 2.

If, equivalents of these levels are required for indoor amplified music annoyance they can be found from equation 2, e.g. a 'good standard' for night time noise within dwellings with windows closed is 35 CNL hence using this figure as the EAL in equation 2, the measured $L_{eq,T}$ will be:-

$$L_{eq,T} = 35 - 20/0.7$$

$$= 21dB$$

63Hz and 125Hz octave band centre frequencies.

Table 2 - Measured levels (Col 4) to give an equivalent to the corrected levels (Col 3) for indoor amplified music annoyance.

Col 1	Col 2	Col 3		Col 4	
	L_{10} (18 hour)	Corrected noise		$L_{eq,T}$ dB	
	dB(A)	dB(A)		Octave band 63Hz and 125Hz centre frequency	
		Day	Night	Day	Night
Maximum noise level within dwellings with windows closed	50	55	45	50	35
"Good standard" of noise within dwellings with windows closed	40	45	35	35	21

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If the "Good Standard" values in column 4 and column 3 are not exceeded then annoyance should not be caused. It is interesting to note that at the level and frequency of the sound in column 4 it will almost certainly be inaudible and the full circle is complete. The difference is, the suggested levels are derived from experimental evidence and not used just because of a failure to correlate common sense with sound measurements. The levels up to the maximum noise level in Table 2 could be acceptable in some circumstances but will be audible.

THE MEASUREMENTS

The next problem is however, how do you measure 21dB octave band at 63Hz and 125Hz centre frequencies when this could be 10 to 15dB below the existing background noise?.

Many ways exist, in signal processing techniques for measuring signals "buried" in background noise, however, these may be too involved to justify their use for amplified music noise assessment.

One possible solution is the use of narrow band or third octave band analysis. The example in figure 3 shows random white noise at an overall level which is approximately 8dB above a bass drum noise. It can be seen here that the peak at 65Hz still exceeds the white noise. The drum noise level will, of course be regularly fluctuating in time and hence can be easily recognised. Converting the same signals to octave bands (figure 4) shows that all octave bands of the bass drum noise are below the octave bands of the white noise, this makes practical measurements more difficult. Figure 5 shows the same signals again, but converted to third octave bands. The level of 63Hz third octave band centre frequency of drum noise is well above the level at 63Hz third octave band centre frequency for the white noise.

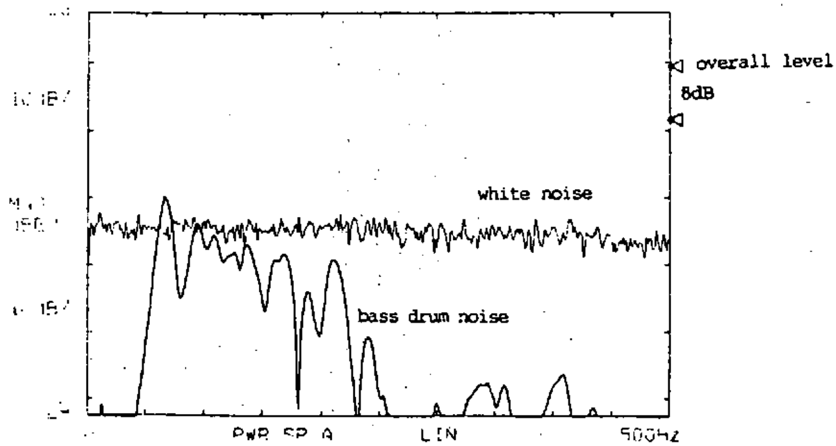

Figure 3 **Narrow band white noise at an overall level of 8dB higher than a bass drum noise.**

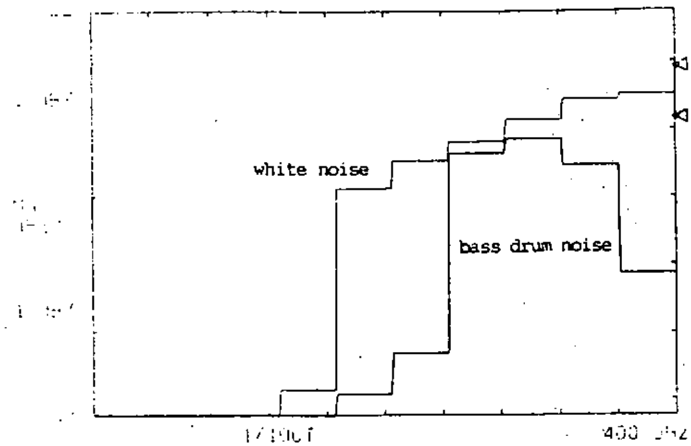

Figure 4 As figure 3 but in octave bands.

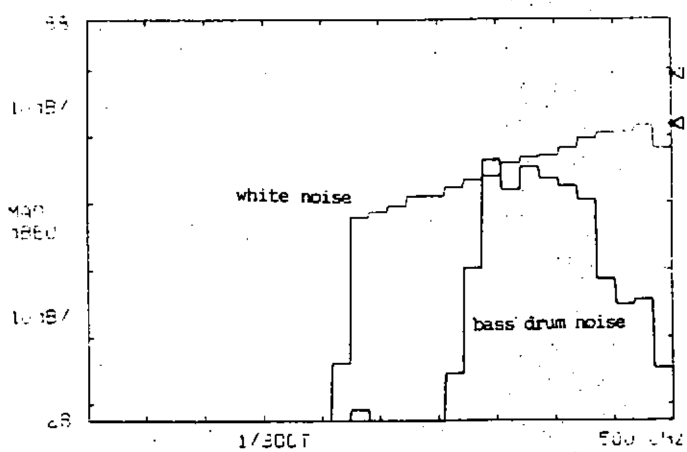

Figure 5 As figure 3 but in 1/3 octave bands.

Another way to obtain the results is to take the measurements outside the dwelling of the complainant. Sound insulation of between 10dB and 20dB can be expected, for these frequencies, depending on the window type and seal etc. [13].

Hence noise levels outside of the dwellings should be 31 to 41dB for the "good standard" at night. Care should be taken with this method as 'standing waves' can sometimes occur within dwellings.

CONCLUSIONS AND SUMMARY

Inaudibility, as a criterion came into use for amplified music annoyance assessment due to the poor correlation between the annoyance and the measured 'A' weighted sound pressure level.

Experimental evidence shows that the 'A' weighting is not relevant to the perception of a bass drum noise.

Experimental evidence shows that, for the annoyance attribute, the perception of a bass drum noise is asymmetrical with loudness.

A simple model has been developed to take the above points into account for an objective criterion for indoor amplified music annoyance.

Measurements may require narrow band or third octave band frequency analysis.

Although progress has been made, further research is still required to take all the variables of annoyance from amplified music into account.

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