AN INVESTIGATION OF AMPLIFIED MUSIC DISTURBANCES IN DWELLINGS

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INTRODUCTION

More and more cases of amplified music disturbance are being referred to Environmental Health Departments for investigation. Environmental Health Officers (EHO's) ask complainants to keep a diary of disturbances over a period and if deemed necessary the EHO will visit the complainants' house to make noise measurements and form a subjective impression of the case. However, without clear guidelines it is difficult to relate such measurements to an acceptable rating of *Annoyance* and lay the basis for legal action. This study relates to the development of a rating scheme for amplified music disturbances which would form a reliable benchmark to which cases could be referred.

1 STUDENT DATA

Each year data is sent in to the O.U. by students of the T234 course *'Environmental Control and Public Health'*. Students are given Type 3 sound level meters and asked to make measurements of domestic and environmental noise, but of interest here are the measurements of amplified music listening levels. The sample number for 1990 was 393. Of the 1990 students, 40.2% lived in semi-detached houses, 34.6% in detached, 16.8% in terraced and 8.4% in flats.
Students were asked to set the volume of their Hi-Fi to what they considered to be 'Quiet', 'Typical' and 'Loud' settings. Table 1 shows the overall mean values for the 1990 students. The mean values of 53.7, 63.24 and 74.75 are all within 0.5dBA of the 1989 result, thus showing good consistency. A 10dBA difference is apparent between the three level categories, the levels themselves being a useful benchmark for calculations of noise levels in typical situations.
Dwelling type was not found to significantly affect listening levels; however, regularly users of Personal Cassette Players (PCPs) have listening levels on average 2·3dBA louder than those who don't. T-tests between the means of those who do and do not use PCPs show significantly higher Quiet and Typical levels but not for Loud level. The preferred music type of the student was found to be important.The levels for those who listen to *Rock* music are slightly higher than either *Pop* or *Classical* by a margin of 1 to 2.5dBA. T-tests between Rock and Non-Rock listeners show significantly higher Typical and Loud levels but not Quiet. The way people rate the loudness of their own listening level was tested by asking them to rate their own listening levels as either Very Loud, Loud, Quiet or Very Quiet. The Very Loud and Very Quiet subjective rating have only a sample number of 11 between them so are only of limited use. However, the difference in levels given by those under Loud and Quiet subjective ratings is very clear, at least a 3dBA difference for 1990: very close to the result for 1989. T-tests between those who rated their levels as Loud and those who rated their levels as Quiet show significantly higher levels for the former for Quiet, Typical *and* Loud levels. The sex of the student has not been found to significantly affect listening levels.

The following table lists how often students in the four dwelling types are disturbed by their neighbours.

	Disturbed by Neighbours? [percentages]		
Dwelling	Never	occasionally	Frequently
Flat	21	58	21
Terrace	45	45	10
Semi-	53	43	4
Detached	66	31	3

In total 53% of students are never disturbed by their neighbours, 40% occasionally and 5% frequently. The trend of the data is predictable; most flat dwellers are disturbed *occasionally* while most detached dwellers are *never* disturbed. When it comes to concern over disturbing neighbours, Flat, Terraced and Semi-detached dwellers are very similar: around 80% are concerned. For detached dwellers this figure is 67%.

2 Transmission of Music Signals Through Walls

2.1 Analysis of Music Spectra

A wide selection of music types have been fed through an FFT analyser, programmed to average the signal spectrum over a period of about 30 seconds to 1 minute. Typically this involved setting the number of samples to either 32 or 64. The music example given here is Thomas Dolby's 'Airhead' a typical full bandwidth multi-instrument Pop/Rock piece. The spectrum is presented with bandwidths of 1kHz and 10kHz in Figs. 1 and 2. Fig. 1 shows a distinctive downward tilted character above about 1kHz, around -6dB/Oct in this case; -10dB/Oct is typical for Orchestral music. Below 300Hz the classical sound tends to remain flat down to around 60-70Hz where it rolls off at approximately 24dB/Oct, and has a region of ambient noise in the 10-30Hz region. The rock spectrum on the other hand has a rising tendency below 300Hz down to its roll-off below 30-40Hz, again approximately 24dB/Oct (fourth order). Particular music forms such as Choral, Piano, Organ and Drums each have their own spectra distinctive of that instrument or form.

The conclusion that can be drawn from the spectra we have examined is that the signals are generally pink noise in nature. Such a spectrum, high pass filtered at a frequency of around 20-40Hz would appear to be a good approximation to long-term averaged music signals. The possibility of approximating reproduced music signals in such a way is very useful when calculating typical transmitted noise levels and making in-situ measurements of noise transmission.

2.2 Predicting Likely Transmitted Noise Levels

The calculations that follow are for transmission through two wall types; Model I is based on the BS5821 reference values for *good* insulation and Model II is a wall of *poor* insulation. Assuming that (i) the source spectrum is high-pass filtered pink noise, (ii) the typical background noise level is 25dBA, (iii) source levels are 53, 63.5 or 74dBA and (iv) wall characteristics conform to either

Model I or Model II performance, one can make some instructive calculations of the audibility of music signals under different conditions. We should point out that no allowance is made here for non-ideal loudspeaker or room responses, in practice both of these will alter the spectrum of the transmitted sound.

Experiments with a filter designed to simulate a Model I wall transmission characteristic have shown that such a wall reduces the A-weighted level of the pink noise spectrum described above by 50dB. For our Model II wall we assume an equivalent transmission loss of 40dBA. The transmission of the three levels above, corresponding to Quiet, Typical and Loud listening levels, gives the following result:

Source Level/dBA	Transmitted Noise levels/dBA Model I	Model II
Quiet/53	3	13
Typical/63.5	13	23
Loud/74	24	34

It is reasonable to assume that the noise becomes audible when its level is comparable to that of the background level of 25dBA. In the case of the Model I wall only the loud level should be audible. For the Model II wall the typical level should be audible and the loud level clearly so. We can deduce from these results that with the Model I wall a signal is only likely to be perceived as annoying when the source level is Loud, this is consistent with the label of *'good'* insulation. For the Model II wall both Loud *and* Typical levels are likely to cause annoyance; this is consistent with the label *'poor'* insulation.

3 Analysis of Case Studies of Noise Nuisance

Data is available from around thirty case studies of noise nuisance referred to the noise group of Birmingham Environmental Services. Data is in the form of calibrated tape recordings, with real time clock, made in the complainants' house.

Presented below is data from one of the thirty or so cases studied, all of those studied are from the Birmingham area. Fig. 3 shows an analysis of data taken at one site. This Figure shows the relative amplitudes of the music noise spectrum, upper curve, and the background spectrum, lower curve. The background has a peak in amplitude in the sub-200Hz region, falling off slowly as the frequency increases. The noise spectrum differs from the background mainly in the mid-bass region, 100 to 400Hz where the difference reaches 15dB in parts. Narrow band low-frequency characteristics are clearly visible at 70 and 100Hz: in this region below 100Hz one has the bass drum and bass guitar signals, often noted as being the main cause of annoyance in a transmitted signal. It is worth noting that room standing wave effects could be contributing to the narrow-band features here, particularly as the background spectrum contains similar features.

Fig. 4 shows the level difference between the transmitted music spectrum and the background spectrum. This is a useful format because it more clearly illustrates the frequencies at which the music signal will be most clearly audible. It is possible that the integral of this curve could be a very useful measure of the audibility of transmitted noise.

4 Derivation of a Model for Assessing Complaints

The use of rating schemes to assess community reaction to noise sources is well established. Assessment of the impact on the community of industrial noise, for example, has lead to the development of rating schemes which predict the likely reaction to a new noise source in the different parts of the neighbourhood, [1,2]. For example, the A-weighted noise level is measured or predicted, and corrections added for noise characteristics, time of day of the disturbance, its duration each day and the likely background noise level. The corrected level then falls within limits which can be related to the community reaction.

It is likely that the assessment of the annoyance of amplified music may be approached in a similar way. The rating scheme outlined below closely parallels other existing rating schemes; this is a logical move from the technical point of view and its subsequent familiar format should aid its acceptance by the acoustics community.

The proposed scheme for amplified music disturbance is illustrated in Fig. 5. It contains the following basic elements:

- *A-weighted* disturbance and background noise measurements
- correction for *time of day* of disturbance
- correction for *duration* of disturbance
- correction for *bass prominence* of disturbance

The use of A-weighted measurements is a debatable one, and is under examination. On the one hand the problem is a subjective one and as such A-weighting is appropriate; but the perceived importance of low frequencies would suggest that a linear weighting might be more suitable. However, if the listener can hear the disturbance through the party wall, and assuming the noise is reasonably broad band, A-weighted levels should be consistent with audibility.

Broadband measurements and weightings are of limited value when the noise spectrum is not broadband but has distinct narrow-band effects. It is often the case in amplified music disturbance that all that can be heard is the narrow band bass 'thud' of a bass drum; often enhanced by the use of the amplifiers' bass tone control. In such cases A-weighting will not give an accurate measurement of the subjective impact and a correction would need to be added; this is the reason for the inclusion of a *bass prominence* correction in the model. One other crucial point here is that most EHOs have little more than a sound level meter with linear and A-weighting facilities, so it is advantageous to base the rating scheme, for the time being at least, on such broadband measurements.

The time of day at which the disturbance occurs is of crucial importance; a disturbance in the middle of the night must be rated as more likely to cause a complaint (and therfore less acceptable) than one during the day. The model allows for three corrections with different magnitudes for daytime, mornings and evenings, and nightime.

The duration of the disturbance is divided into four time periods. The first, less than 20 minutes, is for short term disturbances such as when someone plays only a couple of tracks at a noticeable level. It is reasonable to permit a music lover to play his or her Hi-Fi at a loud level for short periods during the daytime at least, hence the -15dB correction. The second time interval, 20 to 45 minutes, is typical of part- to one whole of an album of music. The third interval, 45 minutes to two hours, covers *extended listening* or listening at several times during the day. The last category, greater than two hours, is for long disturbances tending to continuous; for example, a radio left on for long periods during the day or night.

'Bass Prominence' is a correction for the subjective loudness of narrow-band bass signals such as bass drum and bass guitar. This is a subjective judgement at the moment with a choice of three discrete corrections of 0, +5 and +10 dBA. Objective measures of the bass prominence such as a Linear minus A-weighted measurement have been investigated and may be substituted in due course. In around half the cases investigated the complainant has specifically mentioned the bass content of the music as being a dominant feature of the transmitted noise. It is likely that if the noise in the source room has a natural music spectrum then even though the wall filters in favour of the low frequencies, the listener in the receiving room will unconsciously adjust for the filtering and still perceive the disturbance as being a natural spectrum. Bass prominence therefore will most likely be caused either by the noise maker emphasising the bass with the tone control of the amplifier, from unusual filter characteristics of the wall or from the reproduction of music signals with a high recorded bass level. The bass prominence should be assessed in the following way: if the received spectrum sounds normally balanced, taking into account first the typical wall filtering characteristic, then no correction should be added. Conversely if the low frequencies are very prominent relative to the midband and the sound is little more than a low frequency thump or drone then a correction of +10 should be added. The intermediate case is a spectrum where the midband, e.g. speech siganls, is audible but the overall spectrum is still bass dominant. A certain degree of bass prominance may be caused by a loudspeaker with an extended low frequency response, allowing reproduction down to 20Hz for example. In this frequency region the transmission loss of a typical wall will be at its lowest and structural and acoustic resonances may be excited.

4.1 RESULTS OF THE RATING SCHEME

The case study data passed on to the O.U includes the overall judgements of the EHOs involved in the cases on whether the complaint was justified or not. The rating scheme is judged on its ability to predict the decision of the EHO; however, there is insufficient data at present to assess the variability in the decisions that have been made up to now. So no specific attempt has been made to empirically fit the correction values for duration, time and bass prominence. Rather, the emphasis has been placed on the physical basis of the model and its consistency with previous models for the assessment of community reaction to noise. Fig. 6 shows, for the 29 cases, the median A-weighted levels recorded, these range from 30 to 55dBA. The non-justified complaints are indicated by the bold squares, and with simply the median A-weighted level as the criterion they are relatively evenly scattered over the range. Fig. 7 shows the same data but with the background noise level subtracted. The data is compressed into a smaller range, around 20dBA, again with the non-justified complaints evenly scattered over the range. Fig. 8 shows the data corrected according to the proposed Amplified Music Rating Scheme of Fig. 5 where rating levels have been suggested as follows: if the corrected disturbance level above backgound, Ldc, is above 10 then the complaint is jusified; if Ldc is below 5 then the complaint is not justified; and if in between then EHO judgement is required. The model is correct in 62% of the cases, it is wrong in 17% of cases, and in the remaining 21% it suggests EHO judgement should be used. Of the latter group of 6 cases out of 29 the EHO verdicts were Yes - 5 and No - 1. This suggests that the judgement band (Ldc between 5 and 10) may be a little high. In general, given the limited data and the likelihood of variability in the subjective judgements of EHOs, the results are encouraging. A point worth noting is that data is taken over a limited period, the decision of the EHO may have been influenced also by subsequent developments in the case.

CONCLUSIONS

A rating scheme is proposed which parallels previous models developed in various areas of environmental noise. The new model is based on A-weighted measurements of noise and background levels; and data on duration, time of day and the prominence of the bass. The latter is a subjective judgement but suggestions are made for objective alternatives. Results of the rating scheme are encouraging; a clear trend is observed between justified and non-justified complaints as judged by the EHO involved in the case, however, more data is needed to test the model in its current form before changes to the model format can be justified.

ACKNOWLEDGEMENT

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REFERENCES

[1] Kinsler and Frey. *Fundamentals of Acoustics*, Wiley, New York (1982).

[2] British Standards Institution. *Method of Rating Industrial Noise Affecting Mixed Residential Areas*, BS4142, BSI (1967).

Table 1: Statistical summary of listening levels (n=393)

Statistic	Typical dBA	Quiet dBA	Loud dBA
Mean	63.24	53.71	74.75
Standard Deviation	7.52	8.06	8.032
Minimum	40	30	45
Maximum	90	78	100
Range	50	48	55
Lower Quartile	58	48	70
Upper Quartile	68	59	80

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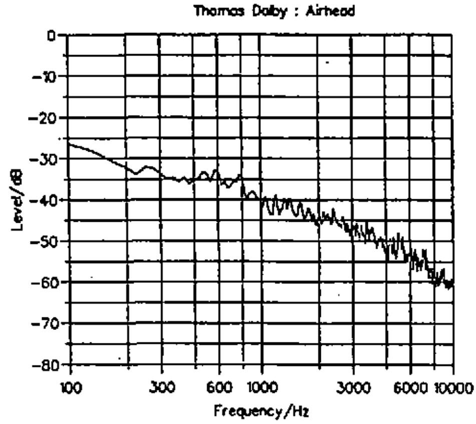
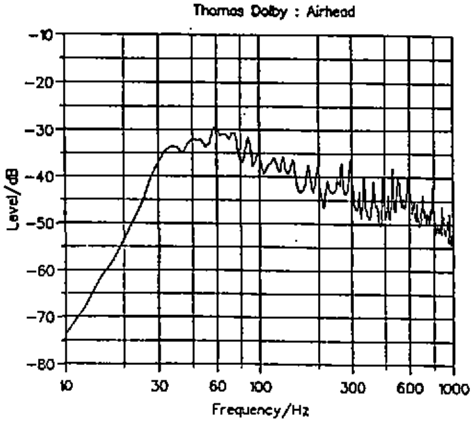


Figure 1



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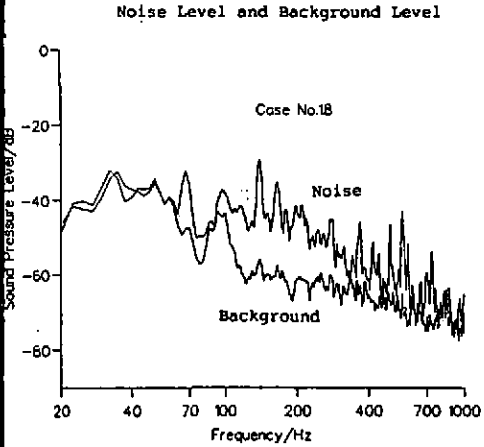

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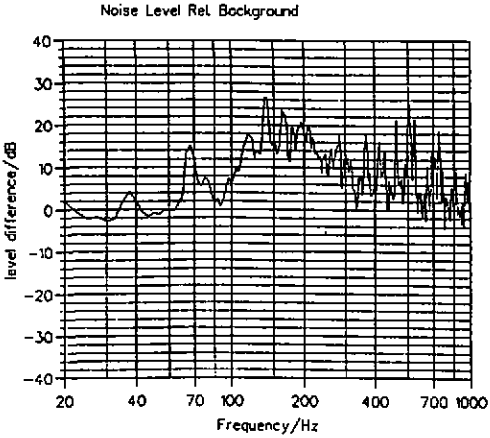

Figure 4

AMPLIFIED MUSIC DISTURBANCES

Calculation of the corrected noise level, Ldc

Measurements : Ld - A-weighted disturbance level

Lb - A-weighted background level

Correction (in dB) to be added, Lc

(i) Time of Day

Daytime :	9.00am - 7.00pm	0
Morn/eves :	7.00am - 9.00am	+5
	7.00pm - 11.00pm	
Nightime :	11.00pm - 7.00am	+10

(ii) Duration of disturbance

> 2 hours	0
45mins-2hrs	-5
20-45mins	-10
<20mins	-15

(iii) Bass Prominence

Not prominent	0
noticeably	+5
very prominent	+10

Corrected Noise Level, Ldc = Ld + Lc - Lb

Suggested rating levels:

Ldc >10 : complaint justified

Ldc <5 : complaint not justified

5 < Ldc < 10 : EHO judgement needed

Figure 5

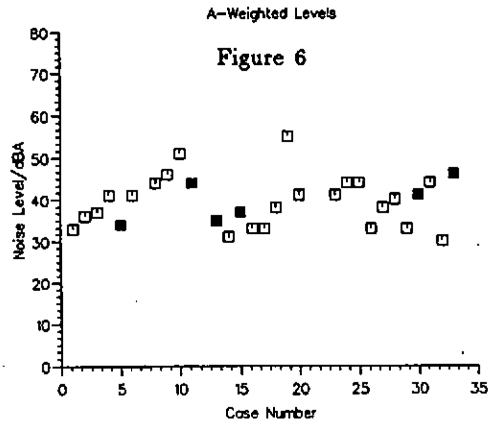

Figure 6

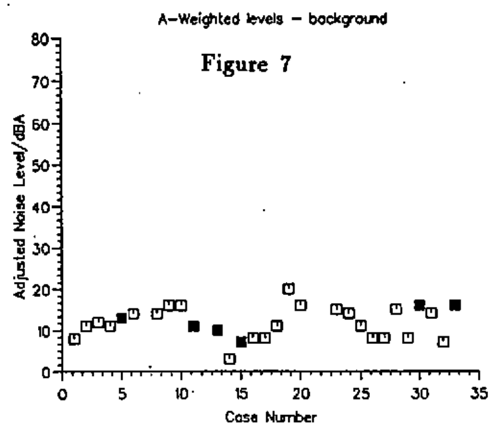

Figure 7

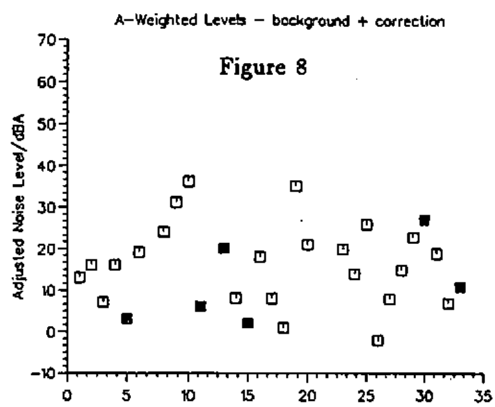

Figure 8