A Study of Annoyance Due to Low Frequency Noise in the Home.

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Abstract

A survey of complaints of low frequency noise was followed by noise measurements in complainants' homes. The survey showed that annoyance was greatest in the late evening and early morning, leading to health problems in some cases. Measurements in the home indicated that the low frequencies at about the I.S.O. threshold level were capable of causing annoyance, especially when the noise fluctuated in level. This sometimes occurred due to a beat between two nearby components. Conventional, dB(A) based, methods of assessing annoyance fail when applied to low frequency noise.

1. Introduction

Prediction of annoyance response of a community to different types of noise – such as aircraft, surface transportation and industry, is generally based on the assessment of loudness and noisiness of the noise. The basic assumption is that the annoyance or disturbance grows with loudness or noisiness. Therefore, an objective measure of the noise is usually made by employing rating scales such as the dB(A), NR, PNdB, etc.

However, when the noise nuisance also involves low frequency noise, much evidence exists to suggest that the annoyance reaction to the low frequency noise is greater than that implied by the estimates of loudness of the noise (1,2). The A weighting scale, which is used almost universally to assess and regulate industrial and transportation noise, takes little account of the low frequency sound energy. This practice in industrial noise regulation often encourages machinery manufacturers to concentrate almost entirely on attenuating energy in the middle and high frequency ranges. As a consequence, modern plant and machinery – increasing in size all the time – may be making a growing contribution to the sound energy in the low frequency range. The noise could become subjectively louder although the dB(A) level is reduced.

This paper presents results from laboratory tests and field studies in the home to show that low frequency noise (<200 Hz) close to or just above the threshold of hearing may often cause extreme annoyance. In such instances a simple measurement of noise level in dB(A) is particularly deficient in assessing the annoyance.

Initial interest was in the origin of a "throbbing" noise which allegedly disturbs people in different parts of the U.K. The study was carried out in three stages:–

i) In order to obtain an understanding of the diurnal and seasonal variations of the noise problem, subjective responses were monitored in a detailed long-term survey.

ii) To help distinguish between problems which are self-generated and those which have their origin in external acoustic phenomena, hearing tests were also carried out on complainants in the laboratory.

iii) The subjective tests were followed by field measurements to examine the characteristics of low frequency noise in the home environment, especially in the range 20-200 Hz.

2. Long-Term Survey

A random selection of 40 complainants from Southern England was considered for this purpose. They were asked to monitor the daily variation of the noise, once every hour, rating their subjective response to the noise on a five point scale from 'Absent' through 'Quiet', 'Mild', 'Heavy', 'Very Heavy' and 'Violent' (these are the descriptions chosen by the subjects). Fig. 1 shows a typical response of a subject for different days of a month. Such results, obtained for the whole group over an eight month period, suggested that in general the noise is more annoying between late evening and early morning hours. Thus, during leisure and sleep hours the intrusiveness of the noise is enhanced.

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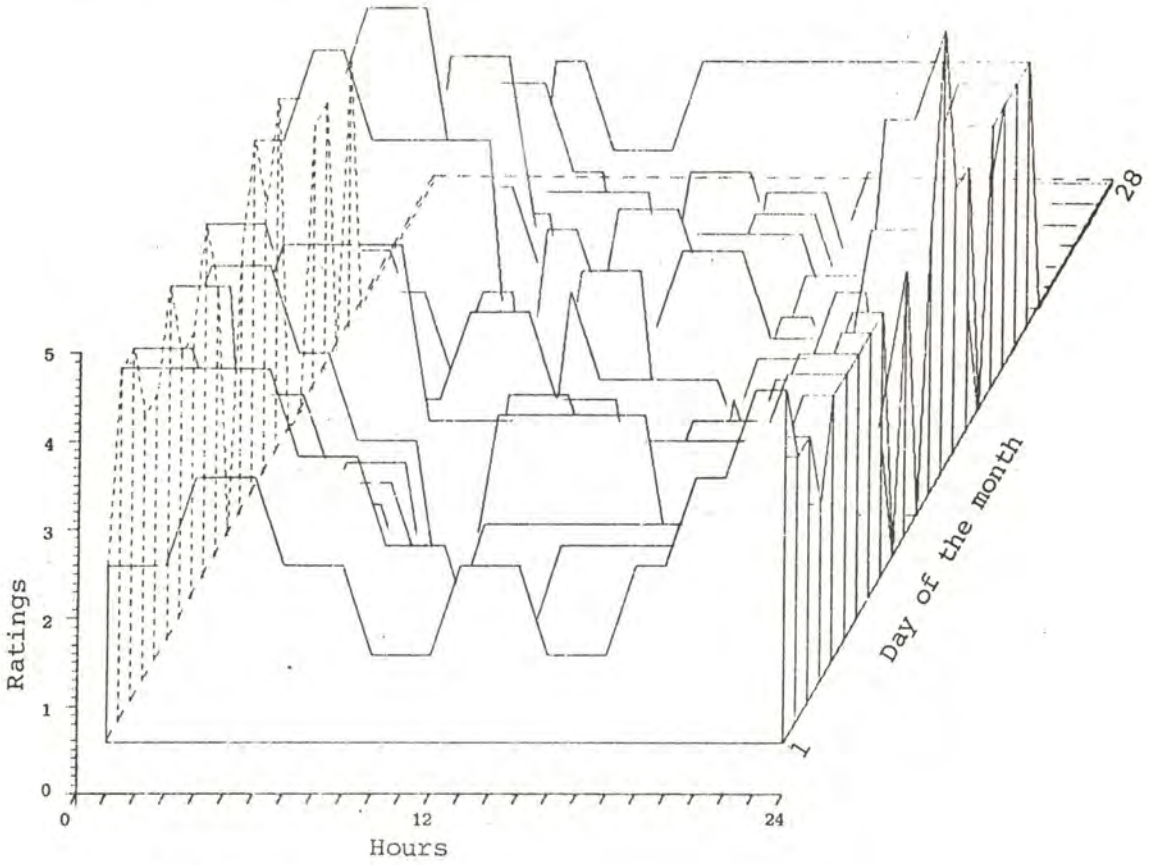

Figure 1 Diurnal variation during August, 1977

3. Hearing Tests and Response to a Questionnaire

From the survey alone it was not possible to distinguish the subjects with hearing disorders from others who are genuinely disturbed by a noise that is of external origin. Therefore, all the complainants were invited to participate in hearing tests in the laboratory. Only 18 subjects were able to take part in hearing tests. Their hearing thresholds were measured in the normal audiometric range (125 Hz–8 KHz) as well as in the low frequency range (20–80 Hz). From these tests, it was possible to isolate four complainants whose hearing thresholds were very poor and whose problems were of a physiological rather than acoustical origin. Two of these subjects were also found to suffer from tinnitus. The hearing of the remainder of the complainant group was sufficiently close to normal to warrant further investigation of their complaints. To clarify this further, it is useful to consider the response of these subjects to a questionnaire in an interview.

During the course of the interviews, it became apparent that the extreme annoyance experienced by the subjects could be regarded as being typical of people who are specially noise sensitive. They usually considered themselves to have acute hearing compared to other members of their family. Very often, the intrusive noise occupies their consciousness to the exclusion of nearly everything else. This leads to several adverse effects such as depriving them of concentration needed for any creative work (painting, writing, etc.), deterioration in health accompanied by headaches, depression, periods of sleeplessness etc. They also revealed that the major cause of their annoyance was the throbbing character of the noise rather than the level. Apart from their enhanced sensitivity to noise, these subjects appeared to be stable. Further, a parallel investigation (3), demonstrated that the above subjects were sensitive to lower level stimuli. In particular, for given levels, the 20-50 Hz region was most annoying. Thus there is not only a group of sensitive individuals, but they are seriously affected by low level/low frequency noise.

However, laboratory studies may bear little relation to the real life situation, and as such are of limited use (4). A voluntary listener in the laboratory is unlikely to produce the same reaction as one who suffers from the intrusion of the noise in real life. i.e. in the home during unwelcome times such as periods of relaxation and creative effort. To obtain an understanding of the problem it was decided to carry out noise measurements in the home.

4. Noise Measurement in the Home

4.1 Instrumentation

Noise measurements were made in the field by employing a combination of Precision Sound Level Meter (B & K 2209) and Real Time Analyser (PARC 4512). In most cases, simultaneous recordings were also made on a SE Labs Eight-four portable tape recorder. Recordings were used for more detailed analysis. Throughout, care was taken to check the electronic noise floor of the system by using a dummy microphone, thus ensuring the measurement of real acoustic phenomena. The measurements in every instance showed the electronic noise floor to lie well below the recorded acoustic levels.

In order to understand the spectral characteristics of environmental noise which throbs or rumbles (as subjects described) it is essential to carry out a 'fine' spectral analysis of the noise. The frequency range selected for analysis was usually 2-200 Hz and in some instances 2-500 Hz. The corresponding resolution bandwidths are 0.4 Hz and 1 Hz respectively. The total time for a data sample was always 320 secs or more. This ensured an accuracy of ±1 dB with a confidence level of 98%.

4.2 Results

Most of the measurements in a complainant's home were made during late evening or early morning. Prior to the measurements it was ensured that the weather conditions were satisfactory – i.e. free from rain and gusty winds. Further, all domestic electric and gas appliances within the house were switched off during the measurements.

The following is a presentation of results obtained for the different cases studied. It should be noted that most of these complaints were initially looked at by the local authority. Invariably, their initial assessment of the noise problem based on British Standard 4142 ("Method of Rating Industrial Noise Affecting Mixed Residential and Industrial Areas" – 1967, revised 1975), which employs the A-weighted sound level, did not predict the degree of annoyance encountered.

Throughout, the spectral amplitudes are presented in dB (linear) scale and they are compared with the MAF threshold curve (ISO R226, 1961).

Case Study No.1

Fig. 2 summarises the results of measurements carried out in a flat in Woking. The occupant was bothered by an intermittent noise which came on approximately every ten minutes and was clearly audible to her for 3-4 minutes. The indoor spectrum exhibits tone components at 146, 195, 242, 292, 340, 389, 438 and 483 Hz, and their levels are alternately close to and above the ISO threshold. When the intrusive noise was inaudible these components completely disappear. During the measurements the change in dB(A) level was insignificant (28–30 dB(A)). The levels of the peaks varied considerably for different positions within the flat – the highest being recorded in the lounge whilst it was consistently 10 dB lower in the bedroom. In the lounge the levels changed significantly when the doors were opened or closed – thus suggesting the room modes must be partly responsible. Calculations for this location confirmed the existence of a room resonance at 242 Hz. The source responsible for the noise nuisance was a domestic appliance located in one of the flats situated above the complainant's premises.

Case Study No.2

Fig. 3 shows results obtained inside a bedroom, where the resident was disturbed by the presence of a low frequency throbbing noise. When the complainant was able to hear the noise and rated it as being mild, the spectrum shows an increase in level at 38 Hz and 29 Hz of 10 dB and 6 dB respectively. A slight increase in level at 100 Hz is also noticed. However, the overall sound pressure level for the two conditions remained at about 25 dB(A).

The flat was adjacent to a boiler house consisting of domestic central heating and water boiler units. Inspection of Fig. 4 suggests that the central heating units produce a strong tone at 100 Hz. However, when the thermostatically controlled water boiler switched on, the levels around 28 and 38 Hz increased by 44 and 30 dB respectively. The level at 100 Hz on the other hand, remained almost unchanged.

It is interesting to note that the apparently low levels measured inside the flat at 38 Hz (8 dB below the ISO threshold curve) and 100 Hz (close to the threshold curve) were a cause of annoyance to the resident. These, however, are averaged levels. Instantaneous levels exceeding the threshold could result in complaints from a sensitive person. There are no criteria which would have assessed this noise to be excessive but the annoyance was serious enough to compel the sufferer to move house.

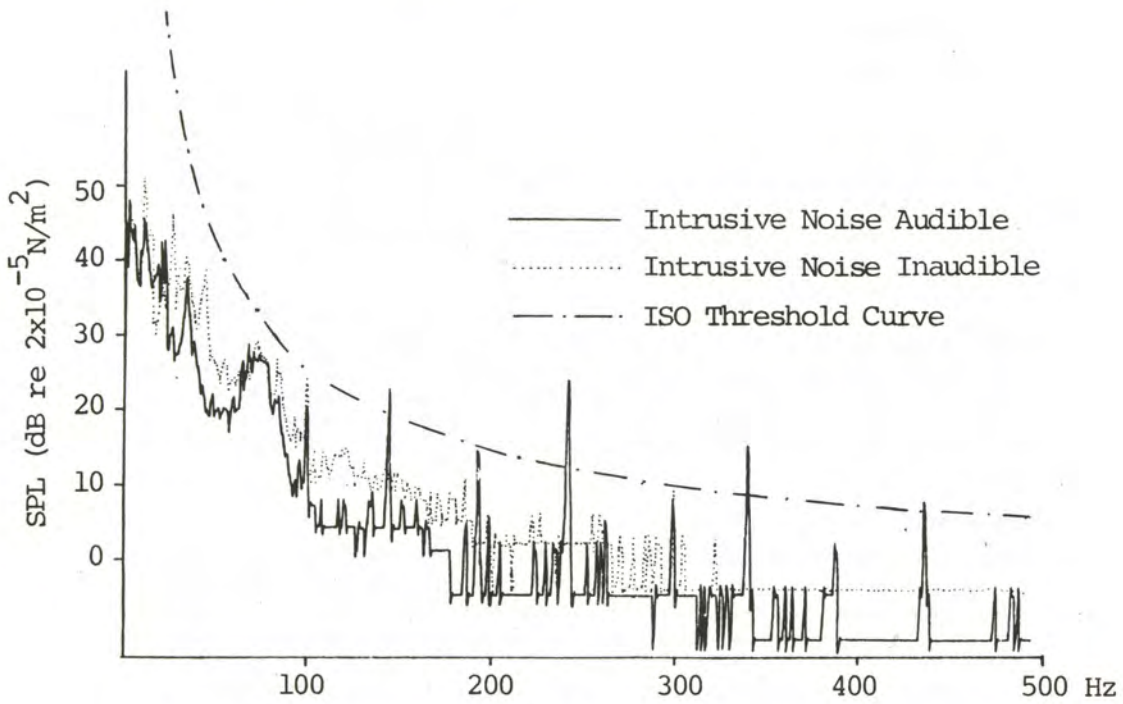

Figure 2 Noise measurements inside the lounge (Woking)

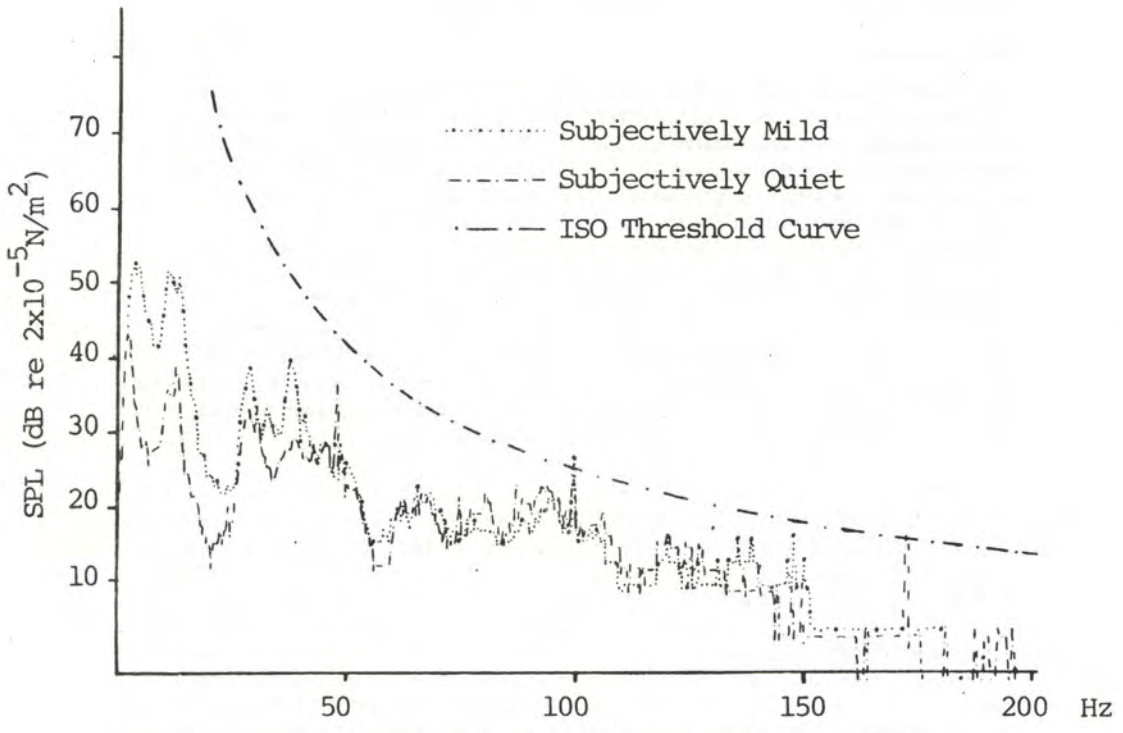

Figure 3 Spectra obtained inside the bedroom (Hampstead Heath)

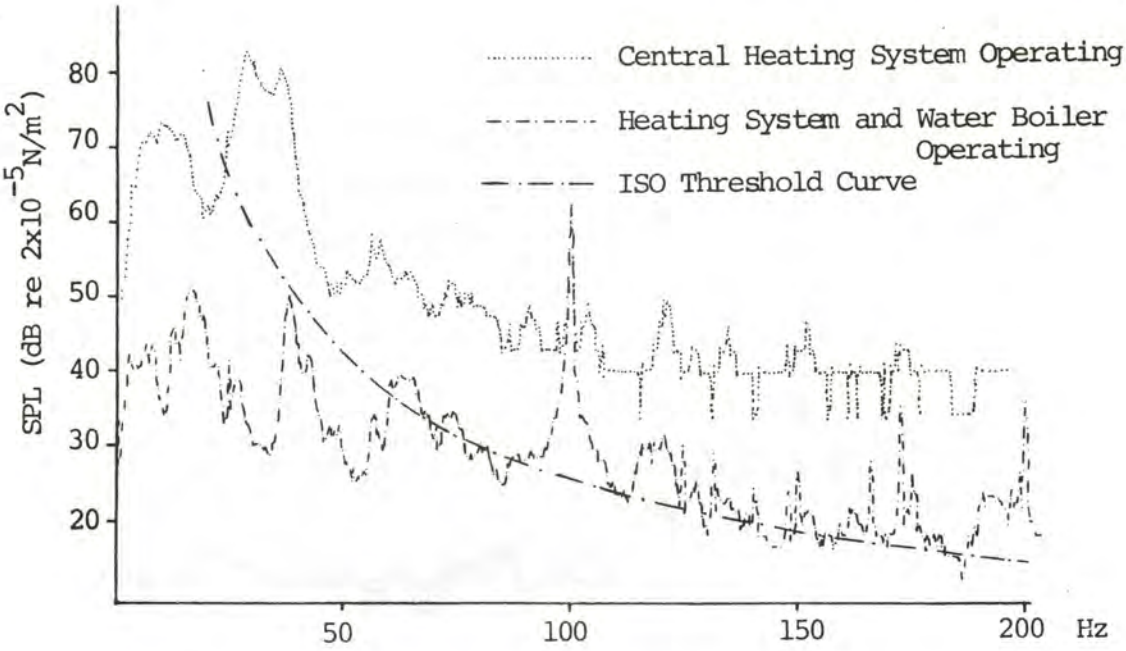

Figure 4 Spectra obtained inside a boiler house (Hampstead Heath)

Case Study No.3

Fig. 5 summarises the results of recordings made at a location in Chiswick. When the noise, which was heard only by the complainant was rated as being 'Heavy', the appearance of a clear peak at 48.8 Hz was noted at a level 15 dB above the 'Quiet' level, bringing it close to the ISO threshold curve. However, the overall sound pressure levels of the two spectra remained much the same at 24–25 dB(A). Repeated measurements at the location confirmed that whenever the intrusive noise was audible to the complainant, the level close to 50 Hz approached the threshold of hearing. Thus, this was the cause of the noise nuisance.

Case Study No.4

Fig. 6 shows the spectra obtained in a residence close to a poultry house. Although the A-weighted reading was only 41 dB(A), the spectrum obtained in the lounge clearly shows double peaks around 60 Hz and its harmonics. Measurements in the complainant's bedroom confirmed the existence of the twin peaks, although at much lower levels. In fact, these levels only just exceeded the threshold, but remained disturbing.

The twin peaks observed in the spectra for this study arose from the slightly different operating speeds of two extractor fans in the poultry house. The resulting beat between the two frequencies is responsible for an unpleasant throbbing sensation. Despite the fact that bedroom levels only just exceeded the threshold, familiarity with the throbbing character of the noise served only to enhance the annoyance potential.

It is interesting to note that, prior to these measurements investigations were carried out by the relevant local authority; however, listening tests over a short time period tended to give less adverse reaction to the noise than those taken over a longer period. In addition, for the low dB(A) levels that were registered, the degree of annoyance was expected to be insignificant. However, soon after this investigation, the local authority took action requiring the cessation of the noise nuisance.

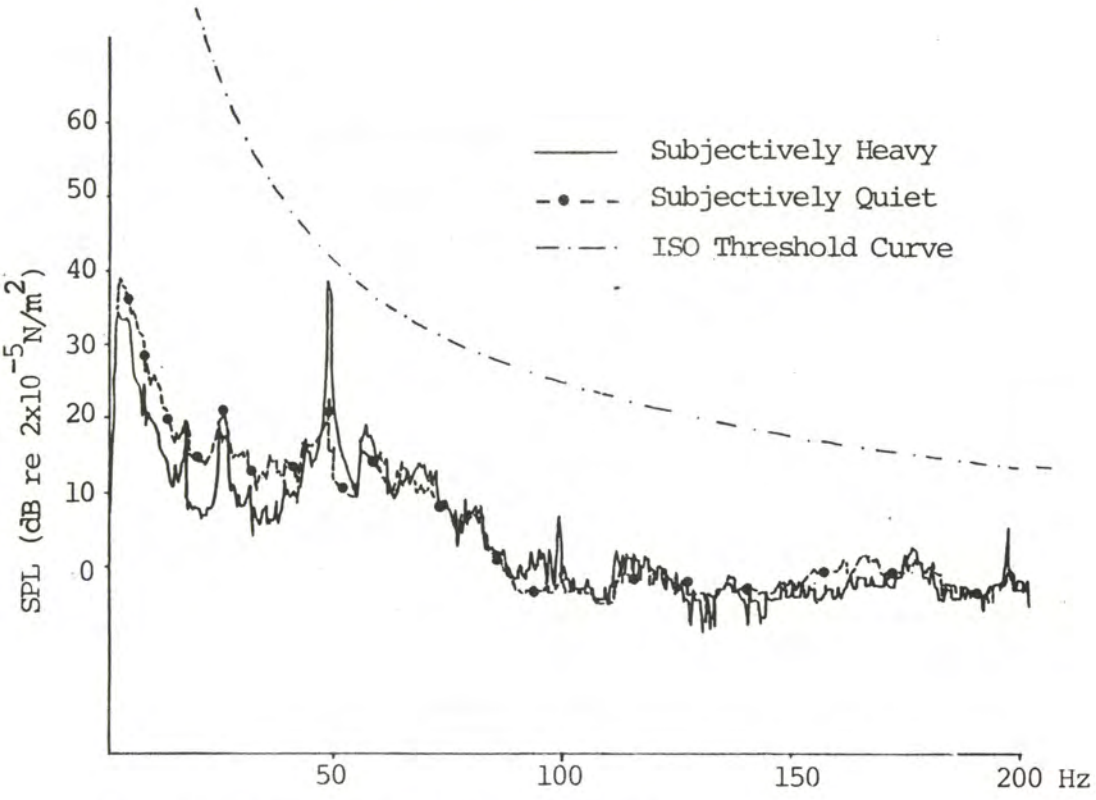

Figure 5 Indoor spectra at a location in Chiswick

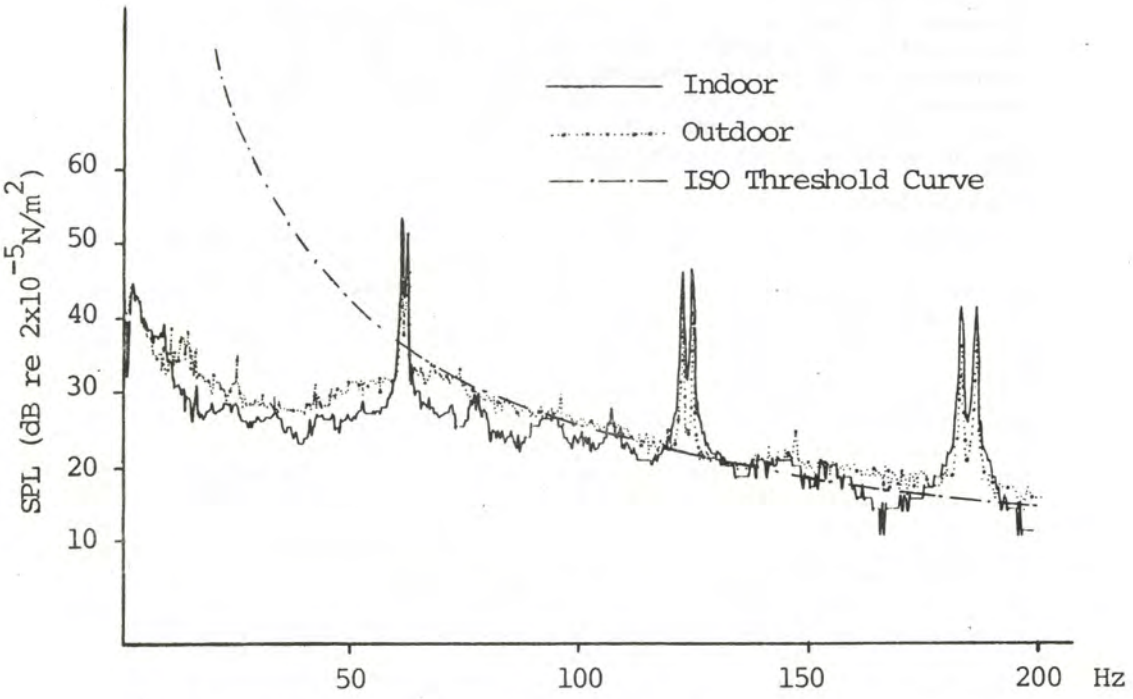

Figure 6 Indoor and Outdoor spectra at Amersham

Case Study No.5

Complaints were received from a self-employed person residing in the Midlands. Apart from the complainant, no other person in his family was able to hear the low level throbbing noise. The noise was particularly audible during late night hours and occasionally during the day as well, whenever the background was free from intermittent traffic noise.

Fig. 7 summarises the results obtained inside and outside the house during late night hours. During the indoor measurement, only the complainant was able to hear the intrusive noise. The spectrum shows some broad band energy around 100 Hz and 130 Hz. It also shows tone components at 208 Hz, 210 Hz and 340 Hz. Generally the indoor levels above 100 Hz lie above the ISO threshold curve and the overall sound pressure level was around 38-39 dB(A). When the windows were opened, a clear throbbing sound could be heard by not only the complainant, but also other people present in the room. The outdoor spectrum displays dominant twin peaks at 208 and 210 Hz at 20 dB higher than the indoor levels.

The indoor and outdoor spectra conclusively prove that the noise nuisance in this case was due to the presence of two closely spaced frequencies – 208 Hz and 210 Hz and was of external origin. Long term monitoring at this location showed considerable variation in level of the pure tone components and levels above the ISO threshold curve were recorded only during late night hours under stable weather conditions. Again, the twin peaks separated by 2 Hz gave rise to a low frequency beat – thus leading to an unpleasant throbbing sensation.

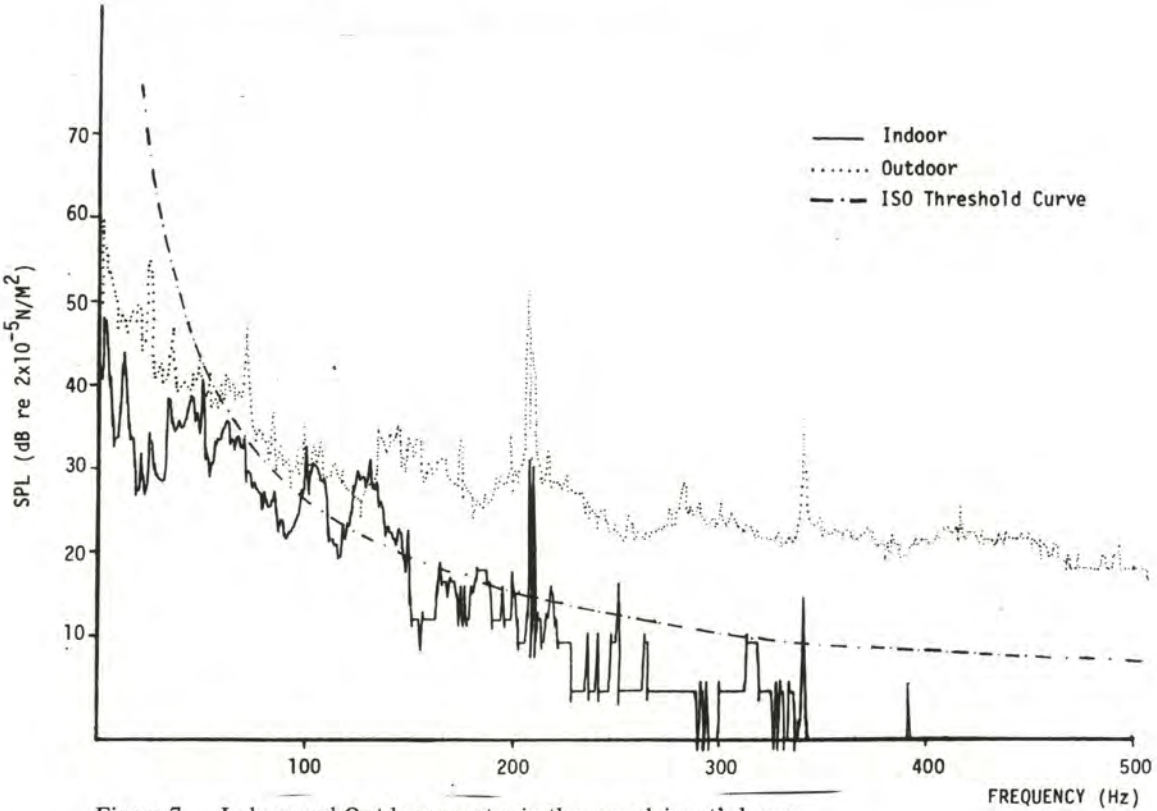

Figure 7 Indoor and Outdoor spectra in the complainant's home

Conclusions

1) Detailed measurement and narrow band analysis of environmental noise has clearly shown the low frequency components responsible for the noise nuisance.

2) Of the five case studies in the home, three gave offending noise levels above the ISO threshold curve and the other two were below the threshold.

3) There are no criteria which would have judged the noise levels in any of the above five cases studied to be excessive. Use of the dB(A) scale by earlier investigators failed to quantify the degree of annoyance actually encountered in these situations.

4) Subjective tests and field measurements show that the annoyance in most instances is due as much to the unpleasant nature of the intrusive noise as to its level. Exposure to such noises over extended periods has resulted in severe annoyance, even at low levels.

Acknowledgement

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