Proceedings of The Institute of Acoustics

THE MICROSTRUCTURE OF THE LOW FREQUENCY THRESHOLD AND ITS EFFECT ON NOISE ASSESSMENT

G.P. FROST

CHELSEA COLLEGE, UNIVERSITY OF LONDON

INTRODUCTION

Annoyance due to low frequency noise is becoming more and more apparent particularly with the increase of larger machinery. Many specific low frequency noise sources are known and a majority of these exhibit spectra, which despite a relatively low dB(A) level, cause annoyance due to their low frequency content. The sparse data available on low frequency auditory thresholds, and on the subjective effects of low frequency noise in the threshold region, indicated that a study of low frequency thresholds and near threshold equal loudness contours would fill a significant gap in the understanding of sound perception in this frequency range.

In the conventional audiometric range, (125 - 8000 Hz), much data has been produced on threshold levels for both Minimum Audible Field (M.A.F.) and Minimum Audible Pressure (M.A.P.), and in particular at octave intervals. This data shows threshold variations between individuals of several dB. Monaural threshold measurements have also shown threshold differences to exist between a subjects left and right ear. More detailed investigation of audio frequency thresholds has shown the presence of sensitivity peaks, with threshold variations of several dB over 1 Hz intervals (COHEN & SCHUBERT (1979), FROST (1981)). The behaviour of the auditory threshold over small frequency increments is known as the threshold microstructure.

1. M.A.F. CURVE ASSESSMENT

The Minimum Audible Field (M.A.F.) curve has been defined as the sound pressure level at the threshold of audibility for a frontal incident sound source in a free field. The M.A.F. curve contained in I.S.O.-226 (1961) obtained from data (ROBINSON & DADSON, 1956), is an accepted reference in many physiological, psychological and industrial noise investigations and assessments [ref. FIG. 1]. Accumulated M.A.F. data for the audio range is shown in FIG. 2 (BERGER, 1981). The diagram clearly shows discrepancy between these results and the I.S.O.-226 curve indicating the necessity for a thorough re-examination of its use at lower frequencies. Results indicate that sensitivities of 5 - 6 dB down on those specified in I.S.O.-226 are possibly experienced for the lower frequency range. A paper by KILLION (1978) also suggests that I.S.O.-226 is in error at low frequencies and presents supporting data to this effect. More recently, data produced by BERGER (1981) again shows a discrepancy, although data was restricted to frequencies above 80 Hz due to equipment limitations.

Figure 1 gives an indication of the relatively sparse data available for the lower frequency range, particularly at frequencies below 100 Hz. Because of this restricted data, no conclusive statements can be made regarding the threshold in this frequency range. It is apparent, however, that the I.S.O.-226 curve as shown in figure 2 is not the best estimate of the M.A.F. as typically measured.

The absolute threshold of hearing, for octave bands of noise with centre frequencies below 125 Hz, behaves in a similar manner to the pure tone threshold (YEOWART, BRYAN & TEMPEST, 1968).

2. THRESHOLD DIFFERENCES

Threshold differences mean that individual sensitivities will vary and, if sensitivity peaks occur as at higher frequencies (FROST, 1981), responses at certain frequencies, as well as at different frequencies, could vary considerably between subjects. Such a threshold difference between individuals could mean that although a particular sound may not be heard by one subject, it is possible that it could be heard by another whose threshold is more sensitive in that region.

This effect could be exaggerated by the existence of sensitivity peaks in a threshold curve. In such a case, the second subject may not only hear a sound inaudible to another, but it may be heard at a subjectively louder level and may possibly result in annoyance. The effect in loudness assessment is emphasised by the fact that at lower frequencies, the equal loudness contours lie closer together than in the mid-frequency range.

The following example will help to demonstrate the possible effect of the existence of a threshold difference or sensitivity peak, on the loudness of a sound experienced by two individuals. (Refer to figure 1):-

A low level pure tone source of 35 Hz at 60 dB SPL, will remain inaudible to a subject with a threshold level of 62 dB SPL at this specific frequency. To a subject with a lower auditory threshold in this region, or a sensitivity peak at the same frequency, reducing the threshold level to below 55 dB SPL, the stimulus will not only be heard, but the subject may experience a loudness sensation in the order of 20 PHON, i.e. the subject may hear the stimulus at a loudness equivalent to 20 dB SPL of a 1000 Hz tone. This sensation could lead to annoyance. This example may be extended to Perceived Noise Contours.

This hypothetical example is based upon a threshold difference in the order of 10 dB between two subjects. In the mid-frequency range, threshold differences in excess of this have been recorded, and threshold microstructure sensitivity variations in excess of 7 dB have been measured between small frequency increments. Conventional audiometry also demonstrates the existence of threshold differences between individuals.

Loudness and annoyance, due to threshold variations, may be emphasised by the possible existence of similar conditions in the equal loudness contours.

It can be seen from these possibilities that a detailed study of the nature and magnitude of such differences existing in the low frequency range, will produce data of use in the assessment of noise annoyance.

3. EXPERIMENTATION

The experimentation involves detailed and accurate measurement of individual threshold microstructures over the lower frequency range, i.e. at 1 Hz intervals between 30 and 150 Hz. Using the data obtained, an assessment of any threshold variations and individual low frequency sensitivities may be determined. The possible existence of sensitivity peaks, such as those sometimes present at higher frequencies, may also be examined. The measurements also include detailed examination of the equal loudness contours in the near threshold region over the same frequency range.

Threshold detection employed a pure-tone air-conduction technique, using decision criteria similar to that used in conventional audiometry. The difficulties in threshold detection peculiar to the lower frequency range, are mainly those of generating the pure tones required, and the accurate measurement of the true sound pressure level present at the ear canal itself. Both of these problems together with obtaining the extremely low levels of background noise required for such testing, have been the major limiting factors in previously conducted low frequency investigations.

The problems of establishing the beginning point of sensation are also of utmost importance (CORSO, 1963). Corso argues that the conventional notion of the threshold is inadequate for locating the beginning point of sensation. Signal detection theory (GREEN & SWETS, 1966) is an extremely important consideration in threshold measurement, as differences of 5 - 10 dB can result, depending on whether subjects first respond when they are sure they hear the signal or when they just think they might hear it. A suitable criteria must be established and adhered to, therefore, for any comparative measurements.

Using the data obtained, a more accurate measurement of the behaviour of the auditory system to low frequencies may be achieved.

REFERENCES

1. E.H. BERGER, 1981. J. Acoust. Soc. Am. 70(6), 1635 - 1645. Re-examination of the low frequency (50 - 1000 Hz) normal threshold of hearing in free and diffuse sound fields.

2. M.F. COHEN and L.P. SCHUBERT, 1979. Acoust. Soc. Am. 97th Meeting. Microstructure of the detection threshold curve.

3. J.F. CORSO, 1963. Psychological Bulletin. Vol. 60. No. 4, 356 - 370. A theoretico-historical review of the threshold concept.

4. G.P. FROST, 1981. Chelsea College, University of London, M.Sc. thesis. An investigation into the microstructure of the auditory threshold between 1 and 2k Hz.

5. D.M. GREEN and J.A. SWETS, 1966. Wiley, New York. Signal detection theory and psychophysics.

6. I.S.O.-226, 1961. R.226 Normal equal loudness contours for pure tones and normal threshold of hearing under free-field listening conditions.

7. M.C. KILLION, 1978. J. Acoust. Soc. Am. 63, 1501 - 1508. Revised estimate of minimum audible pressure: where is the "Missing 6 dB"?

8. D.W. ROBINSON and R.S. DADSON, 1956. Br. J. Appl. Phys. 7, 166 - 181. A re-determination of the equal-loudness relations for pure-tones.

9. N.S. YEOWART, M.E. BRYAN and W. TEMPEST, 1968. J. Sound Vib. 9(3), 447 - 453. Low frequency noise thresholds.

THE MICROSTRUCTURE OF THE LOW FREQUENCY THRESHOLD AND ITS EFFECT ON NOISE ASSESSMENT

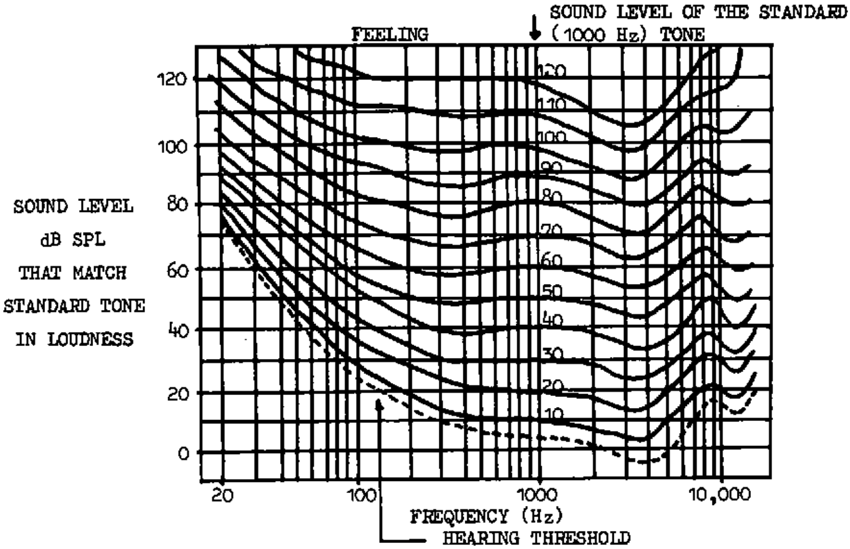

FIG. 1 EQUILOUDNESS CONTOURS FROM DATA OF ROBINSON AND DADSON (1956)

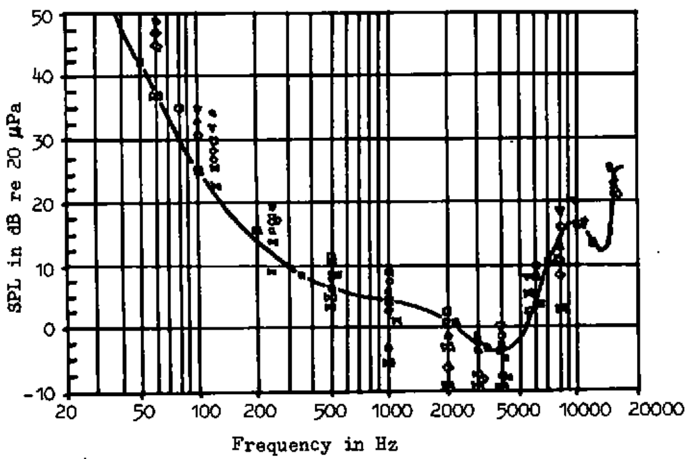

FIG. 2 MAF VALUES FOR STUDIES COVERING THE AUDIBLE RANGE.
(Solid line is ISO R226 curve)