Proceedings of The Institute of Acoustics

THE AUDIBILITY OF SOUND THROUGH WALLS & FLOORS

L S MAIR

GLASGOW COLLEGE OF TECHNOLOGY
GLASGOW G4 OBA

INTRODUCTION

The present study seeks to define inaudibility of music with particular reference to attenuation through walls and floors and using the typical spectral shapes associated with music, with normal background noise and with the attenuations required by the Building Regulations. The ability to hear a signal in the presence of masking noise is of great interest in the field of communications and telephony, although the interest is usually in speech rather than music signals. Speech intelligibility has been widely investigated and there is even an international standard on the measurement of this quantity,

ISO DP 4870 (reference 1). In a review of the prediction of verbal communication in noise LAZARUS 1986 (reference 2) finds good agreement that speech intelligibility reaches 0% in a signal to noise (S/N) ratio of -12 dB. The same author (reference 3) finds that a S/N ratio of -12 dB is 'insufficient for intelligibility' and these general findings are supported by THOMAS & NIEDERJOHN (reference 4), THOMAS & OHLEY (reference 5) and NIEDERJOHN & GROTELUESCHEN (reference 6 and 7). However, none of these authors address themselves to the subject of 'inaudibility' and their work is restricted to speech signals. CRAIK & STIRLING (reference 8) have been able to hear music -15 dB below the background noise level and although their results are in terms of acceptability rather than audibility, only 60% of subjects found the music levels 'acceptable' at -10 dB below the background level.

Experimental system

In order to assess the audibility of music in the presence of noise a series of tape recordings was used. The same sample of music was used for each trial in order to minimise the differences which different samples might produce. The spectrum of the music was corrected for earphone response and for the relative shape of the Building Regulations curves according to BS 5821 (reference 9). Earphones used were Telephonics TDH-39 with MX41/AR cushions and calibration was achieved with an artificial ear (Bruel & Kjaer type 4152) using white noise (HP 8057A noise generator) and an octave band filter set (Bruel & Kjaer type 2203). The spectral corrections for the music are shown in Fig 1.

The masking noise used had a slope of -6 dB/octave from 80 Hz to 10 kHz and this was obtained from the noise generator through filters on the EG & G preamplifier 113. This spectrum (like the music) was then shaped by a JVC (SEA-V7E) spectrum controller to correct for the spectral characteristics of the headphones. The spectral corrections for noise are shown in Fig 2.

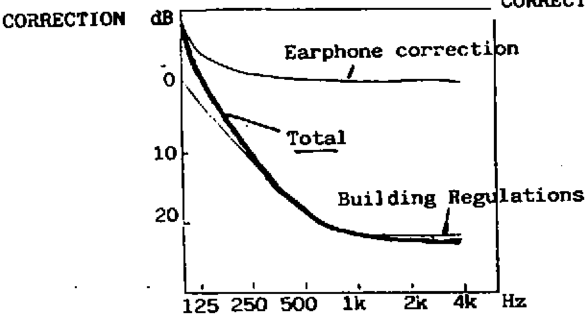

Fig 1 : Spectral corrections applied to music

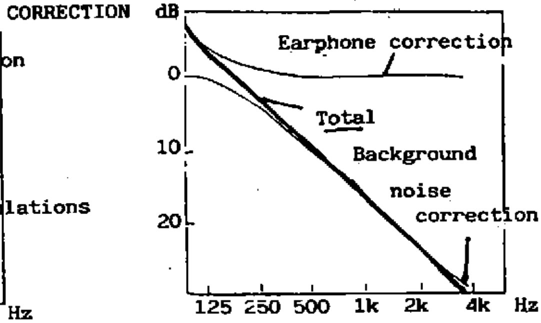

Fig 2 : Spectral corrections applied to noise

At both ears of the subject, therefore, was presented simultaneously (corrected for headphone response) both a typical background noise level and also the sound of music which had passed through a wall providing the kind of attenuation described in the Building Regulations. All measurements were made in an IAC-400 soundproof room whose background levels (with earphone attenuation)are shown in Fig 3. Figure 3 also shows the octave band SPL's measured for the music and for the background noise, using the artificial ear. Four different background levels were used and for each of these, ten different levels of music were used.

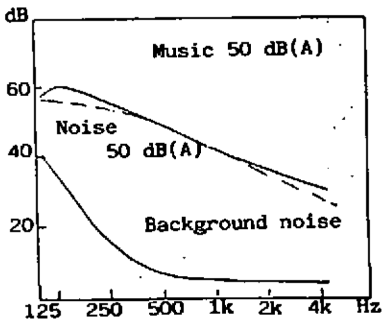

Fig 3 : SPL's for music and for noise each at 50 dB(A)

Test procedures
A tape was composed from these recordings which thus involved 40 different presentations. The levels chosen were background noises of 50 dB(A), 45 dB(A), 40 dB(A) and 35 dB(A) and for each of these the relative music level ranged from -6 dB(A) to -22 dB(A). The presentations were randomised, except that there were four preliminary presentations which were not subsequently counted as part of the test.

Before the 12 minute test each subject was informed that the exercise was a simulation of trying to hear music from a neighbouring room and was asked to mark a list appropriately to indicate audibility. Each subject was asked not to state that the music was audible in the noise unless positive about the judgement.

Test results
The percentage of subjects claiming to hear music in various different background levels is shown as a function of D_A, the level difference between the background and the music, in Fig 4. The following points can be made (all values quoted are L_{EQ}) :

1. There is great uniformity of opinion that where D_A is less than 13 dB(A) the music is audible. 235 out of 240 trials (97.9%) indicated audibility of the music
2. Where D_A is greater than 18 dB(A) the music was deemed to be inaudible by 228 trials out of a possible 240 (95.0%)
3. For 13 dB(A) $< D_A <$ 18 dB(A) the situation is more confused as might be expected from the statistical nature of such an experiment
4. There do not seem to be any significant differences associated with different background levels, indicating that D_A is the controlling factor, for background levels between 35 dB(A) and 50 dB(A).
5. The best fit curve indicates that where D_A = 15 dB(A), 50% of responses indicate audibility and 50% indicate inaudibility.

Interpretation of the masking effect
The results are, of course, dependent on the spectra used and since the music has been attenuated by passage through a wall or floor corresponding to the Building Regulations, this can be used to

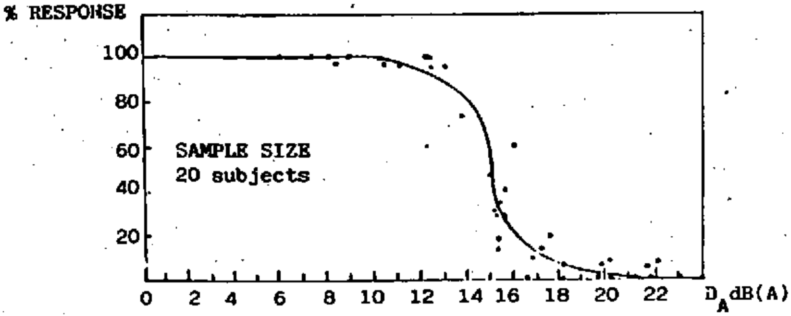

Fig 4 : PERCENTAGE OF SUBJECTS hearing music as a function of D_A the level difference between the background and the music estimate the notional source room level. Thus for example a level at the earphones of 43 dB(A) corresponds to a source room level of 92.6 dB(A) which is a difference of 49.4 dB(A) where the insulation is $D_{nT,w}$ = 52 (AAD = 23 dB). This is shown in Fig 5.

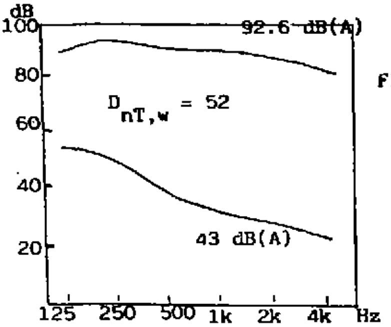

FIG 5 : RECEIVING ROOM LEVEL 43 dB(A) and notional SOURCE ROOM LEVEL 92.5 db(A) for $D_{nT,w}$ = 52

According to LEE (reference 10) when a flat spectrum (not music as in this case) is used an AAD of 23 dB is obtained for a level difference of 51.5 dB(A) between source and receiving room.

It can be assumed that for all insulations the difference between the source room level and the receiving room level ($L_2 - L_1$) is related in the same way to the $D_{nT,w}$ value as in this case where

$$L_2 - L_1 = D_{nT,w} - (52 - 49.6)$$

because the nature of use of the $D_{nT,w}$ process is such that the same spectrum is always used (reference 9).

It also seems reasonable to assume that the limit of music audibility in a background noise is achieved at L_1 = BACKGROUND LEVEL - 15 dB(A). Hence for inaudibility :

$$D_{nT,w} = L_2 - (\text{BACKGROUND LEVEL} - 15\ \text{dB(A)}) + 2.4\ \text{dB(A)}$$

which is $D_{nT,w} = L_2$ - BACKGROUND LEVEL + 17.4 dB(A)

This inaudibility condition is shown in Fig 6 as a graph of source level (L_2) as a function of Background level for a varying parameter of D_{nTw}.

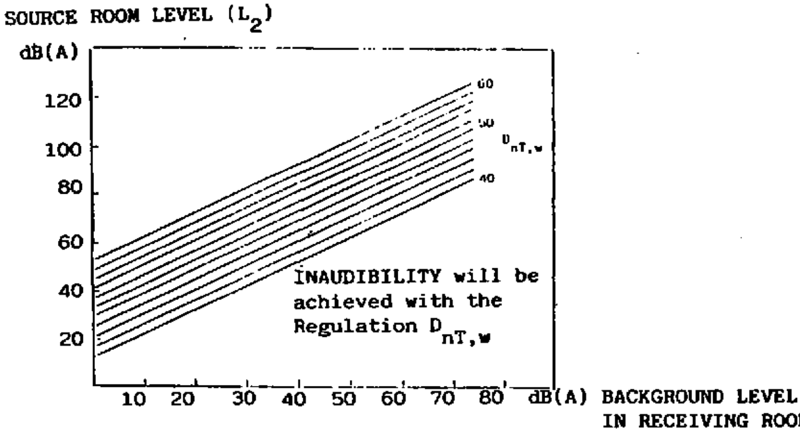

Fig 6 : Music level in Source Room (L_2) as a function Background level in Receiving Room with the value $D_{nT,w}$ required to achieve inaudibility.

Assuming a value for D_{nTw} of 52 and a typical background level of 35 dB(A) this implies that a source room level of 69.6 dB(A) will be audible in the receiving room.

SUMMARY & CONCLUSIONS

Using background noise levels between 35 dB(A) and 50 dB(A) the audible sound levels of music transmitted through a barrier have been measured. For the spectra used an attenuation of 50 dB(A) corresponds to a value of $D_{nT,w}$ = 52.

In the simulation used it was found that the receiving room levels had to be less than the background levels by at least 13 dB(A) and preferably more than 18 dB(A) in order to achieve inaudibility. A working value of 15 dB(A) is taken for the 50% response and as a result the required insulation $D_{nT,w}$ can be stated in terms of the source room level [L_2dB(A)] and the normal background level of noise.

It is seen that the criterion of inaudibility leads to quite severe restrictions on the source room noise levels, even for acceptable insulation between dwellings.

REFERENCES

1 ISO DP 4870 (1975) 'Recommended methods for measuring the intelligibility of speech'

2 LAZARUS, H 'Predictions of verbal communications in noise' A review, part 1 Applied Acoustics 19 (1986) 439-469

3 LAZARUS, H 'Prediction of verbal communications in noise' A review, part 2 Applied Acoustics 20 (1987) 245-261

4 THOMAS, I B & NIEDERJOHN, R J 'The intelligibility of filtered-clipped speech in noise' Journal of the Audio Eng Soc (1970) vol 18, No 3 pp 299-303

5 THOMAS, I B & OHLEY, W J 'Intelligibility enhancement through spectral weighting' Proc IEEE conference on speech communications & processing (1972) pp 360-363

6 NIEDERJOHN, R J & GROTELÜESCHEN, J 'The enhancement of speech intelligibility in high noise levels' IEEE transactions on Acoustics, speech and signal processing (1976), vol ASSP-24 No 4 pp 277-282

7 NIEDERJOHN, R J & GROTELUESCHEN, J 'Speech intelligibility enhancement in a power generating noise environment' IEEE Transactions on Acoustics, speech and signal processing (1978), vol ASSP-26 No 4 pp 378-380

8 CRAIK, R J M & STIRLING, J R 'Amplified music as a noise nuisance' Applied Acoustics 19 (1986) pp 335-356

9 BS 5821 (1984) Rating the sound insulation in buildings and of building elements

10 LEE, L J A simplified field method for measuring the aggregate adverse deviation of partitions Applied Acoustics 16 (1983) pp 335-368