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SPECIFYING THE SOUND LEVELS FOR AUDITORY WARNINGS IN NOISY ENVIRONMENTS

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INTRODUCTION

Auditory warnings presented in a noisy environment need to be loud enough to be heard reliably, yet not so loud as to annoy or disrupt thought or communication. In practice these requirements are likely to be met if the sound levels of a warning's spectral components are between 15 dB and 25dB above the masked threshold imposed by the noise (Patterson 1982). To measure masked thresholds in each environment would be impracticable. A desk-top computer program has been developed which will predict masked thresholds in a given noise environment from the measured existing noise spectrum. The program, its accuracy and use in determining the sound levels needed for auditory warnings in helicopters is outlined.

THE THRESHOLD PREDICTION PROGRAM

The threshold prediction program calculates a masked threshold as a function of frequency by modelling the auditory filtering processes of the ear. The input to the program is a narrow-band spectrum of the masking noise. Threshold at any frequency is determined by calculating the shape of the auditory filter centred on that frequency, weighting the noise spectrum by the filter shape and integrating the noise power within the filter passband. The signal-to-noise ratio at threshold is then applied to give the predicted threshold sound pressure level. The auditory filter shapes used are Patterson et al's (1982) rounded exponential (roex) models with bandwidths a function of centre frequency (Moore and Glasberg 1983).

VALIDATION OF THE PREDICTIVE MODEL

The model has been validated by a direct comparison of measured and

predicted thresholds. Ten subjects wearing flying helmets were exposed to recorded Chinook, Sea King and Lynx helicopter cabin noise, played at realistic levels in the Helicopter Noise Simulator at RAE Farnborough. The threshold for each ear of each subject in each noise was calculated from the noise spectrum measured with miniature microphones at the ears. The lower of the left and right ear thresholds was taken as each subject's predicted threshold at each frequency. Each subject's pure-tone threshold was also measured directly at frequencies from 100 Hz to 4 kHz using Bekesy audiometry, with the tones presented through the communications telephones in the helmet.

A helicopter spectrum at the ear provides a severe test of both the masking model and the noise analysis equipment. It contains high level low frequency components, tonal components and an extremely wide range of noise levels. Nevertheless a high correlation was obtained between mean measured and mean predicted thresholds as summarised in Figure 1. The most simple roex(p) filter shape was not bettered by more complex models.

SPECIFYING AUDITORY WARNING LEVELS FOR A HELICOPTER

Figure 2 illustrates the specification of warning levels for a military Sea King helicopter. The noise spectrum, Figure 2(a), was recorded at the ear during a routine flight. It includes steady noise from the communication/intercom system but excludes intermittent speech. The frequency resolution is 8 Hz. The predicted masked threshold is shown in Figure 2(b), and the recommended range of levels for auditory warning components, between 15 dB and 25 dB above threshold, in Figure 2(c). Finally Figure 2(d) shows the voltages required at the telephone to produce the sound levels shown in Figure 2(c) allowing for the telephone's uneven frequency response. The broken line in Figure 2(c) and 2(d) corresponds to 90 dB SPL at the ear for comparison. Figure 2(d) provides a template to which warning sound spectra are tailored.

Although only one application is described the threshold prediction program is entirely general and not limited to helicopter noise.

REFERENCES

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Figure 1. Mean predicted and mean measured thresholds compared. Each point is the mean for 10 subjects at one frequency in one masking noise.

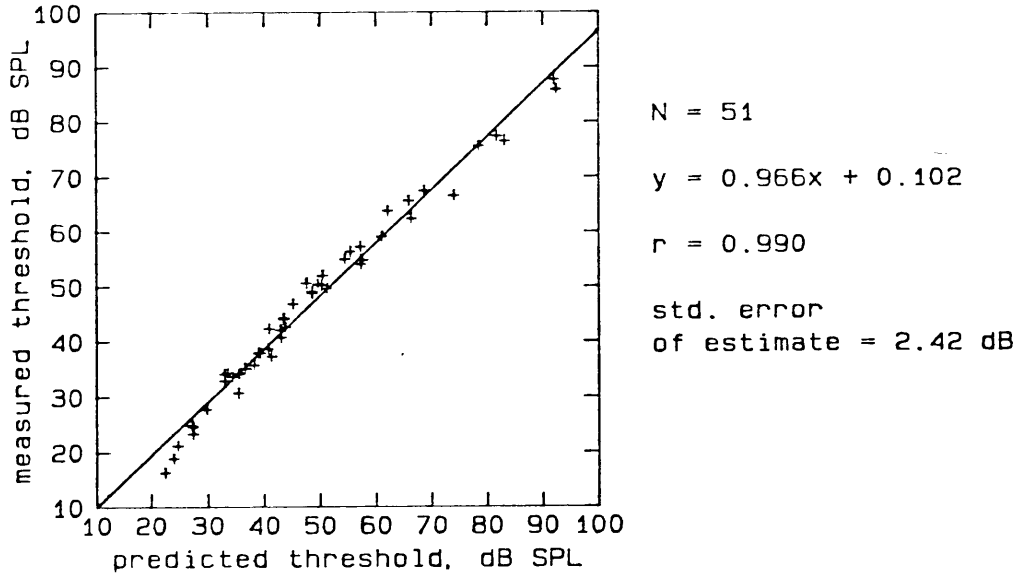

Figure 2. Stages in specifying warning sound levels for a helicopter. (a) noise at the ear, 8 Hz resolution (b) predicted threshold (c) range of recommended levels for auditory warnings, (d) telephone drive voltages needed to produce those levels. The broken line shows 90 dB SPL.