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THE ACCURACY OF MEASUREMENTS MADE IN ROOMS

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INTRODUCTION

Even in specially designed rooms the sound pressure level at one location in a room will be different from the sound pressure level at another point in the same room. Therefore to obtain the true mean sound pressure level it is necessary to measure the level at every location in the room. However this is clearly not possible and for practical purposes measurements are only made at a finite number of positions. As the mean sound pressure level is measured at only a few positions in the room there will be a difference between the true mean and the measured value. This is the error in the measurement due to incomplete spacial averaging.

Schroeder (1) has shown that the standard deviation of the readings (measured either in decibels or pressure units) in a reverberant room can be given as a function of the reverberation time and the bandwidth of excitation or measurement. It can be seen in Figure 1 that the equation can be used to accurately predict the standard deviation of measurements taken in a room.

Although the results of Schroeder's work can be applied to measurements made in narrow bandwidths such as 1/3 octave bands or octave bands they cannot be used for broadband measurements. Furthermore although the standard deviation is a useful measure of the variation between individual measurements it gives no indication of the accuracy of the measured sound pressure level.

This paper describes how the accuracy of the mean sound pressure level can be computed and also how the standard deviation and hence the accuracy of broadband measurements can be computed.

BROADBAND MEASUREMENTS

If the standard deviation of measurements made in 1/3 octave bands or octave bands has been predicted then the standard deviation of any broadband measurement can be predicted. The total mean square pressure is the sum of the mean square pressure in each frequency band. The variance (standard deviation squared) of the total mean square pressure is the sum of the variance of each frequency band (2). The ratio of the standard deviation to the mean can be converted into a standard deviation in decibels as shown in the next section.

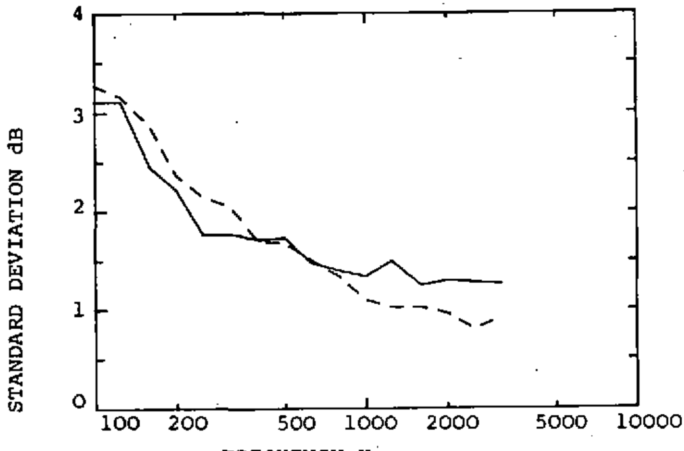

FIGURE 1 Standard deviations of measurements made in a room. ——, Measured, ----, Predicted (Schroeder (1)).

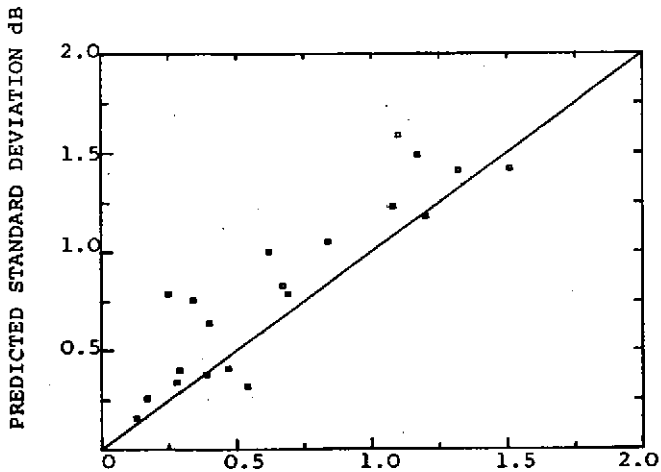

FIGURE 2 A comparison of measured and predicted broadband standard deviations.

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A comparison between the predicted and measured standard deviation for broadband excitation and measurement can be seen in Figure 2 (2). The results show that the actual standard deviation can be predicted to a reasonable degree of accuracy. More detailed analysis shows that much of the differences can be attributed to measurement error though the predicted standard deviation tends to be higher than the measured results.

ACCURACY

If the standard deviation of the readings taken in a room is known then the accuracy of the mean will depend on the number of readings and a factor which is dependant on the probability distribution. For a normal distribution then this factor is the well known Students-t. The actual distribution of the readings will also affect the relationship between the standard deviation of the mean square pressure and the standard deviation of the readings in decibels. This is important as the theoretical predictions are derived in terms of the mean square pressure whereas an answer in dB is more useful.

Although the actual probability distribution of the readings is not known for band limited noise excitation it is sometimes assumed that the mean square pressure readings are distributed with a gamma distribution (3). The other distribution that is of interest is that where the distribution of the readings in decibels is normal. If the distribution is normal then the many statistical tools that have been developed for normal distributions can be applied to sound pressure measurements made in rooms.

The relationship between the normalised standard deviation and the standard deviation in decibels can be seen in Figure 3 (4). The measured data was obtained from a series of tests and involved the calculation of the normalised standard deviation and the standard deviation in decibels from about 5000 sets of 1/3 octave band measurements. Each set of measurements consisted of between 6 and 20 individual readings. It can be seen that there is little difference between the two probability distributions when the standard deviation is small. The measured results tend to lie between the two theoretical curves and at high standard deviations tends to be closer to the result for the normal distribution. When the standard deviation is small then the actual distribution is not important.

Once the standard deviation in decibels has been found the confidence interval can be computed. It is found that the actual distribution is not critical and that similar results are obtained for a gamma distribution and a normal distribution as shown in Figure 4 (4).

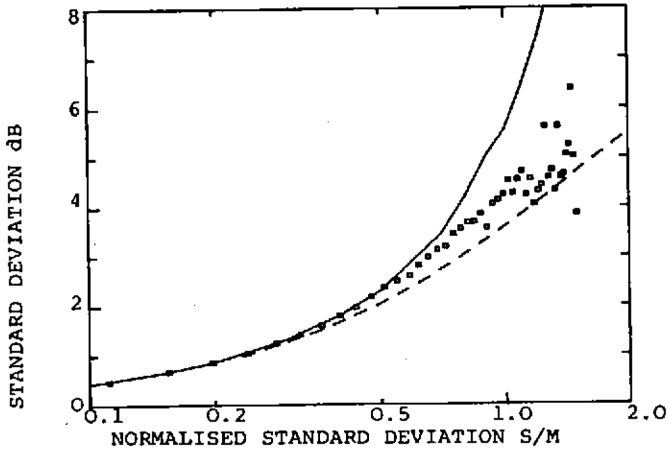

FIGURE 3 Relationship between normalised standard deviation in pressure units and standard deviation in decibels. ——, gamma distribution; ----, normal distribution; ▫, measured results.

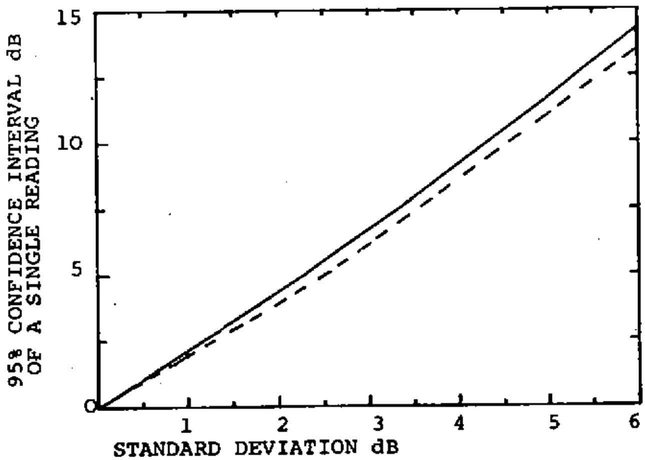

FIGURE 4 Relationship between standard deviation and 95% confidence interval. ——, gamma distribution; ----, normal distribution.

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CONCLUSIONS

These results show that the standard deviation of measurements made in a room can be predicted for both band limited excitation or measurement and for broadband excitation and measurements. The results also show that for most of the calculations the error in assuming that the distribution of the sound pressure levels (in dB) is normal is small.

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