Mistakes, Errors And Uncertainties

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1.0 INTRODUCTION

Most acoustical reports and even papers do not include margin of errors when reporting measurement results. Also, in many occasions assessments are made with only one measurement being taken. This paper examines the possible causes for the lack of statistical analysis in acoustics and makes some recommendations on how to provide more meaningful results.

2.0 SOME (BASIC) STATISTICS

Mistake is the common way of indicating that something that could have been prevented went wrong during a measurement. Examples could be: setting the SLM in dBA while performing frequency analysis, or measuring the noise from a source, while not paying attention to the background noise.

Error, on the other hand, is something inherent to the measurement. It cannot be prevented, but only minimized. Examples could be instrument error, errors due to reflecting surfaces in the vicinity, changing environmental conditions etc. Statistically, an error is the difference between the measured value and the "true" value that is not known.

Any book on statistics will make the difference between a systematic and a random error. The first shifts the mean value of the measurements in one or other direction. We can still have accuracy (good repetition of the results) but not precision (the mean value is shifted with respect to the "true" value). This is a typical error often caused by improper calibration of a measuring instrument. Random error, (probably caused by using instruments with poor accuracy) affects the variability of the measured values. We do get precision, but a large variability.

The most common way of calculating a "true" value is by repeating several times the measurement. Then, this "true" value is calculated as the mean value of those results. However, since the number of measurements is limited, there is a need to calculate the probability that this is really the "true" value. That is when the term of standard deviation comes into play. Its physical meaning is that there is 68% of probability that the "true" value is within the range of the mean value of the measurement results +/- one standard deviation. If two standard deviations are taken, then the probability increases to 92%. If the results of measurement is reported as 85 dB +/- 2.5 dB this will indicate that:

a) We are dealing with a phenomenon where individual observations are normally distributed (as most physical phenomena are),
b) The mean value of the measurements was 85 dBA, and
c) There is a 68% probability that the "true" value will be any value between 82.5 and 87.5 dBA.

Does it means then that this "true" value could be 82.5 or 87.5 dBA. The answer is definitely "YES"! Obviously, this opens the door to speculations, but this is the nature of the beast: we really cannot ascertain the mean value is the "true" one.

3.0 STATISTICS AND ACOUSTICS

Now, what is the situation in acoustics? Measurements are, or should be done following normalized procedures and instruments that fulfill requirements set in standards. In a typical sound level measurement, the accuracy of the calibrator is better than 0.1 dB, same as this of the SLM. However, the accuracy of a field sound level measurement is in the order of +/- 2 dBA. In the case of an audiometric test the situation is similar: the accuracies of the calibrator as well as of the audiometer are a fraction of a dB. However, the accuracy of the measurement itself is between 3 and 5 dB for the air conduction and between 4 and 8 for the bone conduction. The same can be applied to most field measurements, where the accuracy of the instrumentation greatly exceed this of the measurement itself. This is due mainly to the interface instrument – measured object (reflections, background noise, to name some of them).

Surprisingly, even instrument brochures and manuals seldom report the accuracy of the stated characteristics (sensitivity, frequency response, etc).

It should be mentioned, that not many standards include procedures for determining the accuracy of the measurements. In that respect, for instance, the CSA Z107.56 [1] states that:

a) Measurements should be repeated until the differences fall within a certain range, and
b) When measuring noise exposure of groups, a certain procedure should be followed to ensure a given degree of accuracy.

Some ISO standards (e.g., ISO 1996-1 [2], adopted by CSA) requires that the test report include "...uncertainty of the results and methods used to take them into account". Interesting enough, the ISO 1996-2 [3] standard, also adopted by CSA, does not include any requirements regarding accuracy or uncertainty. However, the latest Draft ISO Standard (DIS) 1996-2 [4] does require uncertainties in prediction and in measurements to be reported.

Recently, the International Organization for Standardization (ISO) has issued a directive, that no standard should be produced unless it contains a section regarding the determination of the uncertainty of the measurement.

The issue of uncertainty has become so important that last June in Le Mans (France), the INCE/Europe and CIDB had organized the symposium MANAGING UNCERTAINTIES IN NOISE MEASUREMENT AND PREDICTION including over 125 papers.

From the above it follows that when the uncertainty is an issue, the measurement has to be repeated several times. This, of course, can be a problem in a field situation, where cost and time are an issue.

In summary, this author consider that uncertainty should be determined in the following situations:

a) Laboratory measurements, and
b) When the results are close to limits set by regulating authorities
c) When compliance with a standard has to be demonstrated.

Also, when performing measurements, they should be repeated to confirm the results, especially when

a) Results do not make sense
b) Where personal perception is not baked-up by the measurement results (e.g., pure tones or low frequency rumbling)

Obviously, there is no need to underline the importance of the use of common sense applied to any particular situation.

4.0 REFERNCES

1. Z107.56-94: Procedures for the Measurement of Occupational Noise Exposure. CSA 1994, R2004.
2. Subsection 8.2.1. in CAN/CSA-ISO 1996-1:05. Acoustics – Description and measurement of environmental noise – Part 1: Basic quantities and assessment procedures
3. CAN/CSA-ISO 1996-2:05. Acoustics – Description and measurement of environmental noise – Part 2: Acquisition of data pertinent to land use.
4. Section 12 in ISO/DIS 1996-2. Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels.