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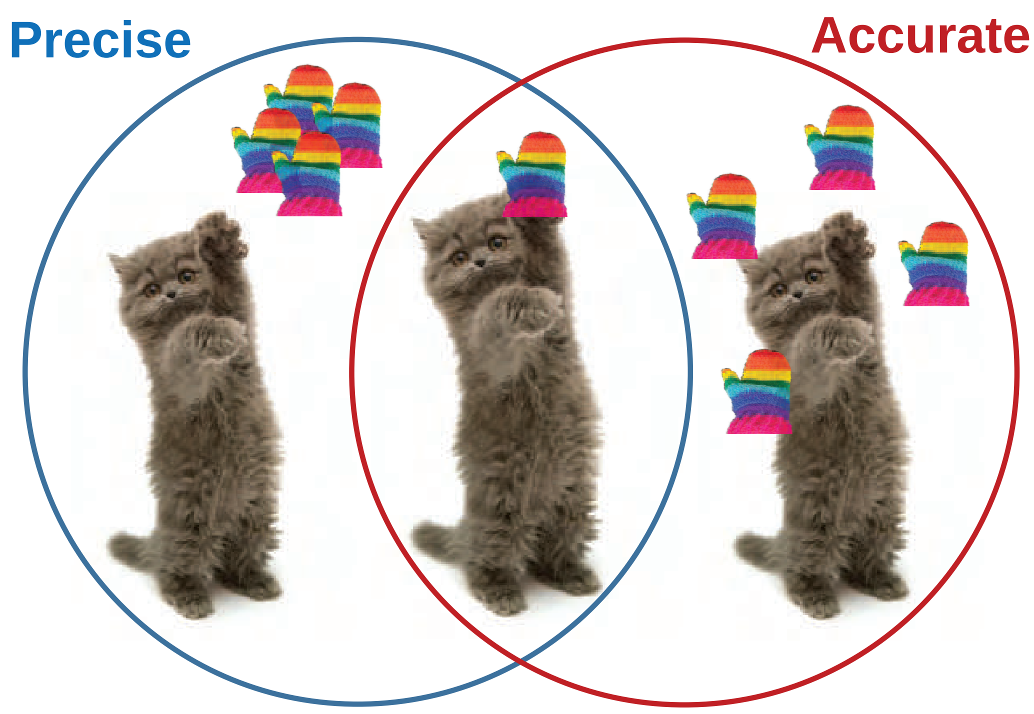
Special topic issue

Uncertainty in acoustic measurements



An introductory guide to uncertainty in acoustic measurements

Uncertainties in Acoustics

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Features

Regulars

Cover Image: Precision and accuracy in 'kitten speak'

Source: Various (recreated by W.H.Page)

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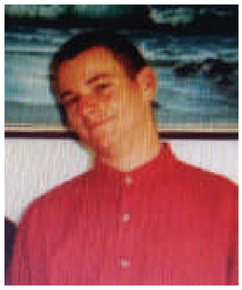
From the President and the Editors

President's Column

Dear ASNZ Members, Associates and Fellows,



Christmas is nearly here and what a year it has been. From months and months of rubbish weather through the winter - with monitoring jobs queuing up, to the last few weeks of pretty-much golden sunshine in many parts of the country. Bring on summer!

Speaking of monitoring, this issue of the journal has a great paper on measurement uncertainty and accuracy. It's something that those of us performing measurement work need to keep in mind all the time. Those figures on the fancy backlit screen of the SLM will always have a complicated story to tell!

Alongside the evaluation of uncertainty and accuracy in measurement is the awareness of and care taken to minimise uncertainties in the prediction of noise levels.

With many of the measurements done these days being used for modelling or predictions of some sort, it is important to remember the limitations of the processes and data. I always remember what was drummed into me by many an educationalist in my youth: "garbage in = garbage out". The sophisticated and nice-looking computer programs these days have a habit of inspiring a sense of accuracy that isn't always there.

With the holiday season coming up, make sure you put down the sound level meters, close the excel spreadsheets with rho's and alpha's and confidence intervals in them ,and spend time with your family and friends to reduce the uncertainty about whether you work too hard.

As usual, thanks to the editors of and the contributors to the Journal – it's another great issue with great local and relevant content. Nice one!

Jon

Editor's Column

Welcome to the third and final issue of New Zealand Acoustics for 2017 (Vol 30, No 3). Its been yet another busy year and the December Edition has once again proven to be a challenge to prepare and get to the printers by the required deadlines.

We have prepared a special edition journal with the theme of 'uncertainty in acoustic measurements'. We also have the Journal's first ever Guest Editor Vern Goodwin who will share his expertise and opinion on the topic of uncertainty in acoustic measurements specific to New Zealand practice. Vern is a well-known and respected acoustician with over 40 years direct experience in the field of acoustics. Vern is employed by Southern Monitoring Services (SMS) as their Environmental Acoustics specialist supporting SMS's Environmental Noise Analysis and Advice Service contract with the Ministry of Health.

The edition also has its regular pieces including our usual news, reviews and events including the RMA.net and Member Profile.

As this is the final edition for the year, we wish to take a moment to thank all those persons (who there are many) who give their time and effort to help prepare the Journal. This includes the Journal Team through to those who allow us to publish their work.

We wish to give a special thanks to Dr Sarah Brand, Editor of RMA.net. We must also not forget the other Editorial team members who provide valuable assistance Dr Grant Emms and Dr Stuart McLaren. Also, last but not least, we must acknowledge Robbie Blacklock our Advertising Manager for his work in this role. We also thank our advertisers for their unwavering support.

Finally, we want to say thank you to our members, we wish you all have a safe and enjoyable break and we will see you all back in 2018 with Vol 31 No 1.

Lindsay & Wyatt journal@acoustics.org

Guest Editorial

Vern Goodwin - Environmental noise analysis and advice service

Students of Massey's acoustics programmes will benefit from this concise introduction to the topic of uncertainty in environmental sound measurement, as will other readers seeking a concise overview and simple explanation. Limitations about the paper's intended guidance are adequately explained at the beginning and end. It excludes application indoors.

Introduction

I recall my first serious consideration of measurement uncertainty was in 1969. It was the real-world problem of why, artillery projectiles were never as accurate as indicated by all the effort and calculations that went into getting them onto target. This was a serious matter for a newly commissioned artillery officer training for war at the School of Artillery, North Head, Sydney, in the aftermath of NZ 105mm gunnery and target errors that had accidentally killed some Australian allies in Vietnam.

Some years later I was contemplating the propagation of sound through air rather than high explosive projectiles. Recalling some of the many variables in ballistics informed my comprehension of why repeatability of measurements outdoors seemed so problematic. Instead of thick books of tables, with all sorts of corrections, maps and long strips of cardboard for insertion into complicated meteorological nomograms and a slide rule, my tools were now a sound level meter and a book of standards, maps, an electronic calculator and a hand-held windspeed indicator. Uncertainty was axiomatic for all measurements of sound waves (or artillery shells) moving through the atmosphere.

How they were accounted for was a problem that could not be ignored. Artillery fall of shot could be adjusted to improve accuracy and compensate for a mass of uncertainties This could not be done for sound emissions. Reproducibility and repeatability of sound level measurements was elusive and experience in the field honed skills all designed to minimise measurement and assessment errors.

Last century the term "uncertainty" was something usually read about in scientific papers, rather than practical field measurement assessments. If anything, it was a convenient unquantified label to explain all sorts of variations to sound level. The label covered all the known errors and was commonly reported as possible cumulative errors of ± a few dB.

Good practice - and bad

Good practice about reducing uncertainty is the key theme of the paper and it naturally features the Salford University good practice guide. A decade back NZAS printed copies of the guide in anticipation of members keen to get a copy because it was mentioned for the first time in a New Zealand acoustical standard, the then newly published NZS 6801:2008. Let's just say it was not a best seller and far too many NZAS members appeared to have preferred to forget the topic rather than get a cheap copy — after a lot of hard work by a few to get reproduction rights and arrange for printed copies at good price.

Reporting on his attendance at several IEC working groups in Frankfurt 1999, the New Zealand delegate Grant Morgan noted significant changes had been agreed in relation to sound level meters and acoustic calibrators. Work has been going on within IEC for many years to replace IEC 60651 and IEC 60804. By 2003 the replacement IEC 61672 now included the maximum uncertainties of measurement within the tolerances. Both Part 1 "*Specifications*" and Part 2 "*Pattern Evaluation tests*" had been prepared jointly with OIML, the International Organization of Legal Metrology. The term "*uncertainty*" was now prominent in standards, and manufacturers' specifications. New Zealand acoustical practitioners could not escape notice of this "new" feature in instrumentation reports and its increasing importance. The paper describes how accounting for uncertainties tended to be ignored or overlooked in environmental acoustics. It reviews some of the early attempts to address the topic in various revisions of acoustical standards.

Reasons why accounting for uncertainties is important are well described in this paper and naturally include consideration of instrumentation and a description of the issues for acoustic modelling as well as occupational noise and environmental noise. (Indoor noise, ie. building acoustics is outside the scope of the paper). For the student audience the thorough coverage of the fundamentals will serve well as an introduction to the topic. As a refresher for acoustical practitioners, the paper is a reminder that the time for a change in attitude to addressing the topic of uncertainty is overdue.

The fundamental question of modelling reliability is posed in the journal paper and the realities for modelling are well understood by practitioners. Predictions are usually made assuming a worst-case, but not extreme worst-case conditions for the single greatest variable -atmospheric conditions, including wind effects on sound level, along the propagation path and at the receiver location. It is the expression of likely sound levels, rather than parameterising their statistical attributes, that informs people about what they may experience. This may be persuasive for a lay audience but creates problems for the profession - if standardised uncertainty reporting is not included or fails to cover the topics well described in the journal paper based on best practice guides and the discipline of uncertainty accounting and reporting.

In modelling, we see uncertainty only arises in computations but the discipline is not the only matter of importance. Individual and community response is a factor in assessment and in Europe noise mapping in accordance with EU directives has to take this into account in addition to measurement uncertainty. For humans, sound is a sensation governed by individual perception and psychology tells us 1 decibel is '*just noticeable*' (for a trained ear under controlled conditions), and 3 decibels is '*clearly noticeable*'. Community response is rarely normally distributed. Measurement uncertainty is one important part of a larger picture. Let's always remember each of us has a unique hearing threshold and no uncertainty calculation takes that into account - a point worth remembering when dealing with individuals seeking to understand reports.

ISO 9613-2:1996 mentioned in the journal paper specifies an engineering method for calculating attenuation of sound propagated out-doors. The accuracy of the method and the limitations to its use in practice are described in clause 9 and is ±3 dB for distances up to 1000 m. I have found more than once that practitioners can be reluctant to acknowledge this. In one incident, I was told I would be undermining confidence in the profession if in my report I insisted in including remarks about the range of possible errors in predictions. Just as well I was not insisting on an expanded uncertainty being reported!

It is instructive to search for measurement reports that mention measurement uncertainty in terms of calculated combined uncertainty. In a random search of noise assessments from New Zealand, Australia, Hong Kong, California, South Africa, Ireland and the UK, it quickly becomes apparent that calculating measurement is usually ignored completely or merely mentioned as a topic with scant explanation of the implications. Some explanations in reports, (I have deliberately not included any examples from New Zealand reports), under headings about the topic of uncertainty included:

- "All measurements taken on site are subject to a margin of uncertainty of ±1 dB due to manufacturer's specification of equipment."
- "To reduce measurement uncertainty the following steps have been taken:" – and then a list of normal measurement precautions plus a statement that "results of each measurement period were reported to the nearest 0.1 dB."
- "To account for uncertainty, 1 dB has been added to the sound power values as a safety factor for modelling purposes."
- (sound levels) were "adjusted by the addition of +1 dB to include a margin for typical test uncertainty values"

...and so on. Including a heading on the topic then deliberately not following any of the "*best practice*" guides for what should be stated appears to be a calculated attempt to mislead the report reader.

International efforts through ISO, IEC, OIML and national standards bodies to include the normal scientific rigor of reporting on measurement uncertainty in new and revised standards should be a strong signal that traditional practices need updating.

The Journal paper makes the point that addressing the topic is not something that can be avoided any more and our profession will be vulnerable to legal inquisition if better practice is not adopted.

Conclusion

My conclusion is that the guide will be a useful introduction for students and a thought provoking refresher for practitioners. The authors of this journal paper conclude "it is only a matter of time before (comprehensive coverage of estimating, handling and reporting of uncertainty) will become a requirement in New Zealand. I am not so sure about that predicted outcome in the short-term and I do not need to quantify my uncertainty, however we should all consider this topic in our future reporting on environmental noise.

Christchurch - 26 November 2017

About the author

Since 1991 Vern Goodwin has served in the Ministry of Health's Environmental Noise Analysis and Advice Service under its former titles of Regional Noise Control Office, Department of Health (1991-1996) and National Environmental Noise Service (1996-2000). He has participated in most New Zealand acoustical standards projects since 1985 and has represented the Ministry of Health on several joint AS/SNZ standards projects. Vern has been a member NZAS/ASNZ since 1982.

AAAC NZ membership expands

In the last edition (Vol. 30, No.2) we announced the AAAC were seeking further New Zealand based consultancy firms. The AAAC have since had their mid-year meeting held in Queenstown. Following our last update we can now report a further group of NZ consulting firms have become AAAC members. To find out more about becoming a member goto www.aaac.org.au

GIB Noise Control® Systems literature updated

After 11 years of service, the GIB Noise Control® Systems literature has been updated with the 2017 edition. The main changes in the 2017 edition are: 1) a refresh of the systems offering has seen the introduction of nine new central barrier intertenancy walls suitable for terrace homes and apartments; 2) For intertenancy floor / ceiling elements, four new floating floor and steel joist options have been included to provide improved noise control performance and choice of building materials; 3) The new steel stud centres and wall heights section provides easy-to-follow guidance to architects, designers and engineers charged with specifying non-load bearing steel frame partition walls; and 4) An expanded system components section near the back of the new literature provides information about some of the products that feature in the expanded range of systems.

A copy can be downloaded from the GIB® Website (www.gib.co.nz) or request a hardcopy version via the GIB® Helpline 0800 229 222

Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to journal@acoustics.org, we would like to hear from you! All comments and feedback is treated as confidential by the Editors.

The Acoustical Society of New Zealand

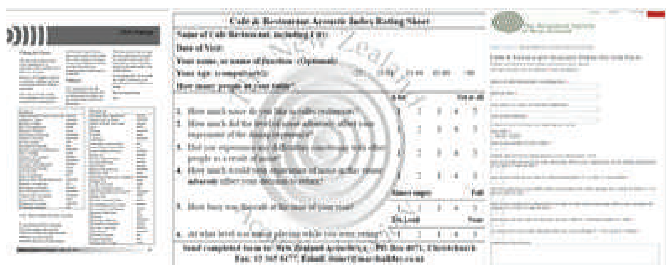
www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal Information and Journal Articles, Continuing Professional Development, Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion, and Contact details of the Society.

Why not visit for yourself?

Cafe and Restaurant Acoustic Index (C.R.A.I.)

The Cafe and Restaurant Acoustic Index, C.R.A.I., is now completely online with all results and online forms able to be viewed and downloaded from the acoustics.org.nz website under the C.R.A.I tab.



International Year of Sound 2020

The Acoustical Society of New Zealand (via the NZ Ministry of Foreign Affairs and the Royal Society) has prepared a submission to UNESCO [United Nations Educational, Scientific and Cultural Organization] in a bid to get the United Nations to declare the year 2020 the '**International Year of Sound**'.

...Continued on Page 12

An introductory guide to uncertainty in acoustic measurements

[1]Lindsay Hannah, Wyatt Page[2] and Stuart McLaren[2]

[1]Acoustic Consultant, Malcolm Hunt Associates, Noise and Environmental Engineers, New Zealand.
[2]School of Health Sciences, Massey University, Wellington, New Zealand.
[1] Email: Lindsay@noise.co.nz

Original peer-reviewed paper

Keywords: Acoustic measurements, uncertainty, accuracy, measurement error, environmental noise, occupation noise.

1. Preamble

This paper has been prepared as part of a chapter on accuracy, uncertainties and errors in environmental and occupational noise measurement. It was prepared by the authors for use in the Massey University course notes for the 300-level course, 214.316 Biophysical Effects of Noise and Vibration.

2. Introduction

In 1977, some 40 years ago now, the 'Comité International des Poids et Mesures[1]' requested the Bureau International des Poids et Mesures[2] recognise a deficiency of international consensus on the expression of uncertainty in measurement and address this problem in conjunction with the then (inter)national standards laboratories and make a recommendation.

The 'Bureau International des Poids et Mesures[3]' then convened a meeting of experts from various countries around the world for the purpose of arriving at a uniform and generally acceptable procedure for the specification of uncertainty. This Working Group on the 'Statement of Uncertainties' developed Recommendation INC-1 (1980), Expression of Experimental Uncertainties [1]. The 'Comité International des Poids et Mesures' approved the Recommendation in 1981 [2] and re-affirmed it in 1986 [3]. The task of developing a detailed guide based on the Working Group Recommendation was referred by the 'Comité International des Poids et Mesures' to the 'International Organization for Standardization' (ISO) [4], as it was believed that ISO could better reflect the needs arising from the broad interests of industry and commerce at that time.

Since the original recommendations of the Working Group and their 'Statement of Uncertainties' on the topic, there has been a variety of international research papers and practice guides on the application of measurement accuracy, uncertainty and error in environmental and occupational acoustics. In New Zealand, however, the topics of measurement accuracy, uncertainty and error tend to be generally either overlooked or only given reference, if any, when being assessed and reported on.

This is not necessarily due to any valid attempt to evade the subject matter, but appears more to be related to the fact that uncertainties have not historically been required. Furthermore, it appears from anecdotal investigations on the issue, that the subject matter can be generally misunderstood and in some cases hard to comprehend. It is also understood that the topic of uncertainty although taught at basic Secondary School Science level, is not always covered, or covered to the required detail within courses on acoustics in New Zealand. Regardless, it is important that both experts and non-experts alike have a basic understanding of the topic and its concepts.

This paper has been prepared first and foremost as a guide to the accuracy, error and uncertainty in acoustic measurement and assessment. It is an introductory guide on the uncertainty of acoustic measurement, for acoustic engineers and students involved in the measurement, assessment and prediction of environmental and occupational noise. This paper explains some of the key concepts to enable the reader to have a better understanding of the subject matter. It covers environmental and occupational acoustics, with a comment on environmental noise modelling and standards. Building acoustics is outside the scope of the paper.

3. Acoustic measurement

A measurement tells us about a quantity of something such as how long or how heavy an object is, with the measurement presented as a number to that property. The term 'measurand' is a technical term often used in science, meaning a 'quantity intended to be measured'. Measurements are made using an instrument of some kind, including the sound level meter used in acoustics to measure sound pressure level or intensity. In the case

1 Comité International des Poids et Mesures from the French translation meaning 'The International Committee for Weights and Measures', Abbreviated CIPM
2 Bureau International des Poids et Mesures from the French translation meaning 'The International Bureau of Weights and Measures', abbreviated BIPM
3 New Zealand is a member of BIPM, see www.bipm.org/en/about-us/member-states/nz

of acoustic measurement, the result can be expressed in three parts, the quantity, the unit and the descriptor; for example, 50 dB LAeq,8h.

In the field of acoustics, the objective of any measurement is to determine the 'true' value, which in itself is an idealised concept as there is no such thing as a 'perfect measurement'. For example, an environmental measurement result is only an approximation or estimate of the 'true' value and thus is only complete when accompanied by a statement of the uncertainty. Any measurement will also have imperfections that give rise to an error in the measurement result.

Traditionally, an error is viewed as having two components; namely, a random component and a systematic component. In acoustics, the result of a measurement is generally determined on the basis of series of observations obtained under repeatable and/or reproducible, conditions. There will always be variations in repeated observations, and these are assumed to arise because of the many intervening variables that can influence results.

In real-life acoustical practice, the requirement to have accurate assessment is key, as the purpose of any acoustic measurement is to provide the best estimate of the true sound pressure level. This must include the consideration of inaccuracies as well as noting any known limitations, qualifications or errors in the overall measurement system or measurement chain. Therefore, any acoustic measurement begins with an appropriate specification of the quantity intended to be measured, the method of measurement and the measurement procedure itself.

3.1 Importance of uncertainty in acoustic measurement

Acoustic engineers will be interested in the uncertainty of measurement because they wish to undertake good quality and accurate measurements and to understand the results when undertaking any assessment. The aim is to be as accurate as possible, as an overestimation of uncertainties could also have undesirable repercussions. The flip side of any 'underestimate' of uncertainties may also cause too much conviction to be placed in the values reported. In both cases this could lead to unintended consequences. For example, financial implications may result if remedial work was required due to an underestimation of a true value. In all cases a "true" value, not a "safe" value, of the uncertainty of each of the results is the overall aim and one primary reason to employ a suitable qualified and experienced acoustical engineer.

4. Key concepts in measurement

4.1 Accuracy and precision

When collecting measurement samples, any valid measurement, including acoustical measurements, will be made with the aim to be a 'true' representation, as well as being accurate and precise. The term 'precision' should not be confused with the term 'accuracy'. However, in many cases people often get the two concepts and terms confused.

The accuracy of measurement is the closeness of the agreement between the result of a measurement and a 'true value'. The term 'accuracy' is a qualitative concept, which relates to the quality of something rather than its quantity. In lay terms, accuracy is how close a measurement is to the 'true' or accepted value while precision can be thought of in terms of the repeatability, or reproducibility of the measurement. In other words, are the results consistent each time a measurement is taken? Thus, the more consistent the results the more precise the measurements.

It is possible to have precise measurements that are not accurate. It is also possible to have accurate measurements that are not precise. Figure 1 illustrates four concepts of accuracy and precision using a 'target analogy', where the aim is to be both accurate and precise in measurement.

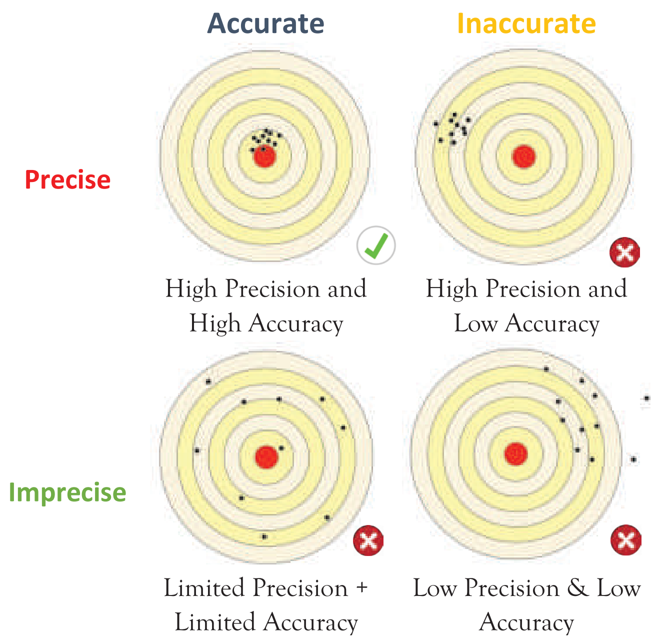


Figure 1: Accuracy and precision – the 'target analogy'

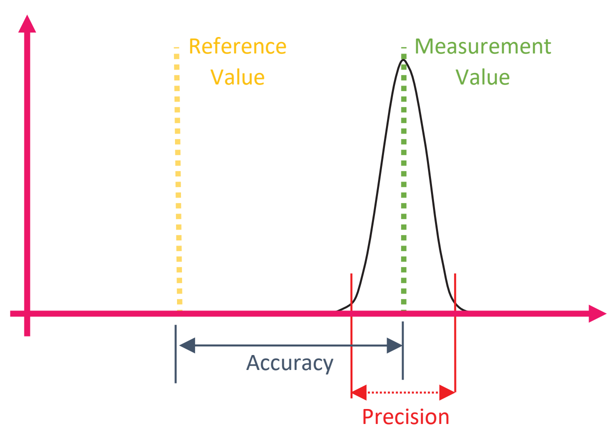


Figure 2: Accuracy and precision – A graphical representation

Figure 2 illustrates the same concepts using a graphical representation.

4.2 Repeatability and reproducibility

Repeatability and reproducibility are two components of precision. Reproducibility is one component of the precision of a measurement or method while the second component is repeatability. Figure 3 illustrates the concept of repeatability and reproducibility.

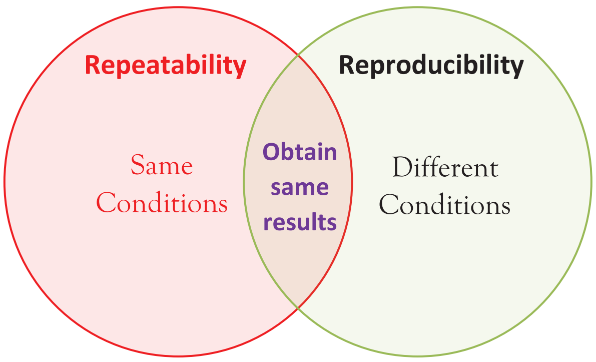


Figure 3: Repeatability and reproducibility

Repeatability is the ability of an acoustic engineer to consistently make the same measurement under the *same conditions*. That is, the closeness of the agreement between the results of successive measurements carried out under the *same conditions* of measurement. Repeatability conditions include (but are not limited to) the same measurement procedure, the same observer, the same measuring instrument (used under the same conditions) and at the same location.

Reproducibility is the ability of different acoustic engineers to consistently reproduce the same measurements under *changed conditions*, this is, the closeness of the agreement between the results of measurements carried out under changed conditions. A valid statement of reproducibility requires specification of the conditions changed. The changed conditions may include (but are not limited to): to the principle of measurement; method of measurement; measuring instrument; locations; time and reference standard.

4.3 Uncertainty

The concept of uncertainty in lay terms means doubt, and thus in its broadest sense "uncertainty of measurement" means doubt about the validity of the true value of a measurement. Although error and error analysis have long been a part of the practice of measurement science and acoustics, the concept of uncertainty as a quantifiable attribute (able to be expressed as a quantity) is relatively new in the history of measurement, as well as the history of modern acoustics in New Zealand.

It is widely recognised that even when all of the known or suspected components of error have been evaluated and the appropriate corrections have been applied, there still remains uncertainty about the stated result, that is, some doubt about how well the result of the measurement represents the value of the quantity being measured.

An example might be that the best produced sound level meter that is a well-known and trustworthy brand will 'give the right answers'. However, what any student needs to understand is that for every measurement there is always a margin of doubt or margin of error. The true value (of a quantity usually being decibels in acoustics) is the value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose.

The uncertainty of measurement is a parameter, associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measurand. The uncertainty of measurement comprises, in general, many components. Thus, when given a measurement result and reviewing uncertainty, it is important to note that there is not one true value but an infinite number of values. These would be dispersed about the presented measured result that is consistent with all of the observations and data and that also has varying degrees of credibility attributed to the results.

Once we understand the concept of uncertainty means doubt, the next concept to understand is how 'big' is the margin or how 'sure' is the doubt. Thus, two further concepts are needed in order to quantify uncertainty. The first is the 'width' of the margin or more widely referred to as the 'confidence interval'. The second is the 'confidence level' which tells us how sure we are that the 'true' value is within the given margin.

An example is the length of a piece of a metal. The metal bar measures 100 ±1 mm at a 95% confidence level. These results can be interpreted in lay terms stating that we are 95% sure that the metal bar is between 99 mm and 101 mm in length. The ±1 mm in this example is the confidence interval (how big is the margin), and the 95% is the confidence level (how sure we are that the 'true' value is within the given margin).

5. Sources of uncertainty

In some publications, uncertainty components are categorised as "*random*" and "*systematic*" and are associated with errors arising from random effects and known systematic effects. This view is not entirely correct. The ideal method for evaluating and expressing the uncertainty of the result of a measurement should be universal. That is, the method should be applicable to all kinds of measurements and to all types of input data used in measurements.

The actual quantities used to express uncertainty should themselves be internally consistent, that is the measurements should be directly derivable from the components. Additionally, they should be independent of the component grouping, and of the decomposition of these components into sub-components.

The quantity used to express uncertainty should also be transferable, meaning that it should be possible to use directly, the uncertainty evaluated for one result, as a component in evaluating the uncertainty of another measurement, in which the first result is used. The uncertainty in the result of a measurement generally consists of several components which may be grouped into two categories according to the way in which their numerical value is estimated: those which are evaluated by statistical methods; and those which are evaluated by other means.

In practice, there are many possible sources of uncertainty in a measurement, including the incomplete definition of the actual quantity intended to be measured, the imperfect realisation of the definition of the quantity intended to be measured and non-representative sampling (the sample may not represent the defined quantity). Other possible sources of uncertainty include inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions, personal bias, approximations and assumptions incorporated in the measurement method and procedure and variations in repeated observations of the quantity being measured under apparently identical conditions.

These sources are not necessarily independent and an unrecognised systematic effect cannot be taken into account in the evaluation of the uncertainty of the result of a measurement, but contributes to its error.

5.1 Good practice to reduce uncertainty in noise measurements

The Salford University '*A good practice guide on the sources and magnitude of uncertainty arising in the practical measurement of environmental noise*' [5] summarises some of the more frequently encountered sources of measurement uncertainty. As shown in figure 4, the contributions to the uncertainty assessment are partitioned into three areas.

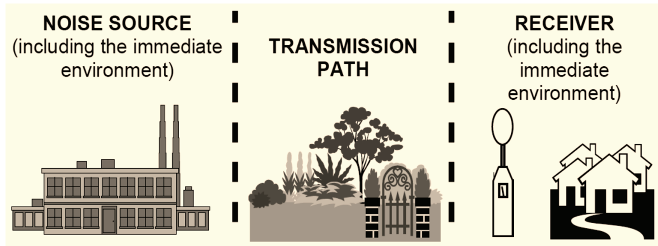


Figure 4: Partitioning of uncertainty assessment

The following list, summarised from the Salford University guide, is an ephemeral summary of some of the good practice measures to follow for the management of uncertainty.

1. The noise source and immediately surrounding environment

Spectral content of the noise emission: *Sources of uncertainty can include sound levels influenced by standing waves / interference patterns/beats and subjective assessment of tonality affected by standing waves/interference patterns]. Good practice includes determining the probability of standing waves and checking for the presence of standing waves, either subjectively by listening in several places around the measurement position, or by observing any change in level. If standing waves are present and cannot be avoided, take a spatial average, either by measuring at several fixed positions, or by slowly moving the microphone around the measurement position, whilst continually logging sound energy. Anticipate significant levels of uncertainty when measuring noise at the extremes of the audio frequency range, i.e. below 125 Hz or above 4 kHz.*

Nature of the noise source: point/line/area: *Sources of uncertainty can include the degree to which a single measurement is representative of a larger area. Good practice includes investigating all noise sources and determining their type, and the likely pattern of propagation plus the effect at the measurement position.*

Running condition, operator preference/machine load: *Sources of uncertainty can include variability in the running condition of the noise source for example operator preference and load. Good practice includes determining which variables may affect the noise emission and record the running condition at the time of measurement as well as considering how it fits in with all possible conditions. If necessary measure under different sets of conditions, the type and number of measurements will depend upon the nature of the task/reason for the measurement. Those conditions giving rise to average/ maximum noise levels may be considered a minimum. If no reliance can be placed on the word of the operator repeated measurements should be considered in critical situations.*

State of repair: *Sources of uncertainty can include variation in the noise emission due to wear and tear and subsequent maintenance. Good practice includes determining and recording the state of repair of the noise source(s) and enclosure(s) as well as carrying out additional checks to determine the likely variation in the level, before and after maintenance.*

Source height: *Sources of uncertainty can include variability in the measured sound pressure level due to the increasing influence of weather with source height or change in ground surface condition. Good practice includes anticipating greater uncertainty when measuring noise from elevated sources, repeat measurements under different propagation conditions if necessary.*

Movement of noise source (sources are stationary or moving): *Sources of uncertainty can include the unknown random pattern of a movable source or the number of moving sources. Good practice includes ddetermining and logging the movement and number of source(s) during the measurement. If the movement follows a routine, measure representative levels for one or more complete cycles.*

Enclosures and barriers close to the source: *Source of uncertainty may include changes to enclosures, buildings, openings in buildings or barriers surrounding the noise source. Good practice includes inspection of the noise source to determine the probable effect of and the possibility of changes occurring during the measurement. List possible changes and periodically check.*

Environmental conditions (weather): *Source of uncertainty include the ambient temperature which may affect the noise source for a number of reasons, including a change in the sound power of the noise source through to a change in the attenuation characteristics. Good practice includes determining the likely effect of changes in the prevailing weather conditions on the noise source as well as ensuring that the noise source is operating under conditions relevant to the purpose of the survey.*

Number of sources in operation and their positions relative to the measuring positions: *Source of uncertainty can include the mode of operation, particularly when concerned with outdoor activities. Good practice includes keeping a record and report the prevailing conditions at the time of measurement.*

2. The transmission path

Weather: *Source of uncertainty can include many things such as meteorological changes during measurements, meteorological conditions different from previous measurement period and meteorological conditions unrepresentative of conditions under which measurements should have been made. Good practice includes a review of the weather forecast when planning measurement sessions as well as keeping a good record of meteorological conditions for the duration of the measurement and avoiding measuring during extreme conditions unless specific conditions are required as part of the measurement or testing, otherwise only conduct measurements during favourable propagation conditions.*

Ground effects: *Source of uncertainty can include variability in the measured sound pressure level due to changes in the ground surface during or between measurement periods and excess attenuation due to the ground dip. Good practice includes avoiding noise measurement during or immediately after precipitation, accompany measurement results with a description of the ground surface between the noise source and measurement position and consider taking a spatial average when measuring tonal noise close to an acoustically hard surface. Good practice also means estimating the source and receiver heights/distance and fully reporting and logging all measurement results. By measuring under conditions favourable for propagation (downwind/temperature inversion), attenuation due to the ground dip will be minimised. Not only will the measurements represent the worst case, usually* *the cause of complaint, but a higher of repeatability will be achieved.*

Barriers: *Source of uncertainty can include variation in the depth of the acoustic shadow cast by a barrier due to changes in the weather and changes to a barrier due to man's activity or the season. Good practice includes noting the potential effect of changes in weather on barrier shadow and having regard for the effect of seasonal changes such as on foliage.*

3. The receiver and immediately surrounding environment

Microphone position: *Source of uncertainty can include not reporting the exact microphone orientation and position with respect to all other significant reflecting surfaces and not checking that small changes in location have minimal effect on measurements. Good practice includes following the standards for guidance as well as ensuring the microphone height and reason for choosing that height should be recorded.*

Instrumentation: *Source of uncertainty can include use of instrumentation with an unknown degree of precision in or as part of the measurement chain and uncertainty associated with the precision of the measurement. Good practice includes ensuring that the whole measurement chain (including field calibrator) meets the required degree of precision and that you report the type of meter and calibrator used with the measurement results together with details of all other instrumentation used. Good practice also means you follow the manufacturers' instructions and standards such as ensuring all noise measurements are conducted using a sound level meters and field calibrators whose conformance and calibration have been checked periodically against national standards.*

Choice of measurement position: *Source of uncertainty can include interpreting measurement results as representative of something other than that which was actually measured and comparing measurement results taken at different positions. Good practice includes ensuring all measurement positions should be selected to minimise the influence, on the measurement result, of all factors other than the subject of the measurement. To enable repeatably, and therefore comparable measurements, the exact location should be reported such as in a diagram or with GPS co-ordinates including distances to all significant reflecting surfaces and other features. When assessing community noise complaints, it is useful to measure at a number of positions around the noise source to build up an understanding of the noise environment.*

Background noise level: *Source of uncertainty can include variable and complex patterns in the noise emission along with large variations in the measured level due to changes in the weather. Good practice includes considering how the weather will affect the measurement result as well as consider how long-term patterns in the noise emission will affect the measurement result.*

4. Key Players

The Assessor (the person carrying out the measurements)

The Complainant (if applicable)

The Client: The Source Owner

Source of uncertainty across these areas can include incorrect measurement planning generally caused by lack or incorrect knowledge of the problem/site/surrounds/source etc. Good practice includes the use of a check-list and a custom before measurement plan before commencing measurements.

6. Calculating uncertainty

To calculate the uncertainty of a measurement, including in acoustics, firstly you must identify the sources of uncertainty in the measurement chain. Then you must estimate the size of the uncertainty from each source and ensure the same units are used for all quantities. Finally, the individual uncertainties are combined to give an overall figure.

There are clear rules to follow for assessing the contribution from each uncertainty, and for combining the overall uncertainties together.

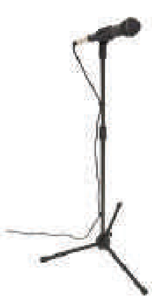
No matter what are the sources of your uncertainties, there are usually two accepted approaches to estimating uncertainty; many text books describe these as 'Type A' and 'Type B' uncertainty evaluations. In most measurement situations, uncertainty evaluations of both types are needed or can be applied.

Type A Evaluation

Type A evaluations are uncertainty estimates using *statistics* (usually from actual repeated measurements). Type A measurement of uncertainty for data is where the distribution of values is spread around the mean (of a normal distribution) and the magnitude of the standard uncertainty can be calculated from repeated measurements. Type A assessments can be for a set of 'n' measurement data with the standard uncertainty associated with the *mean* of that data or the estimated standard uncertainty of any one measurement.

- Standard uncertainty (see Section 6.1) for one measurement is: $u = s$
- Standard uncertainty of the mean (more than one measurement) is given by: $u = s/\sqrt{n}$, where s is the estimated standard deviation (σ_{n-1}) of a set of n data, based on a measure of the spread of results of a limited sample.

When calculating standard uncertainty for each factor or magnitude, Type A evaluation is done with a set of repeated readings enabling the mean and estimated standard deviation to be calculated for the data set.



For example, the height of a microphone on a tripod is measured four times: 1.52 m, 1.50 m, 1.52 m and 1.58 m. The mean height is calculated: x = 1.53 m; and the standard deviation, sd = 3.5 mm. Thus the standard uncertainty of the mean is: $u = sd/\sqrt{n} = 3.5/\sqrt{4} = 1.7$ mm. Therefore, the height of the microphone is 1.53 m with a standard uncertainty of 1.7 mm.

Using the same method, equipment and operator, a second microphone is measured once at 1.51 m. The uncertainty associated with a single measurement may be calculated from the measurements of the first microphone. Standard uncertainty $u = sd = 3.5$ mm. Therefore, the height of the second microphone is 1.51 m with a standard uncertainty of 3.5 mm.

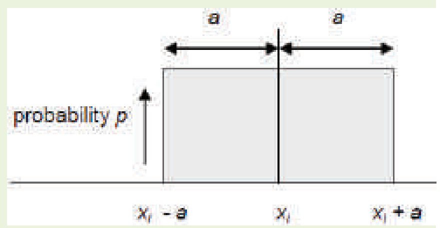
Type B Evaluation

Most other evaluations are Type B evaluations where there is only an *estimate* of the upper and lower limits (± *x*) of uncertainty and we have to assume that the value can fall anywhere between the limits, with equal probability (rectangular distribution).

Type B assessments are generally based on estimates or literature from published data or manufacturers' data for example, as opposed to actual measurements.

Type B Evaluation — Rectangular/Uniform Distribution

Standard uncertainty with equal probability: $u = a/\sqrt{3}$



An estimate of the upper and lower limits (± x) of uncertainty

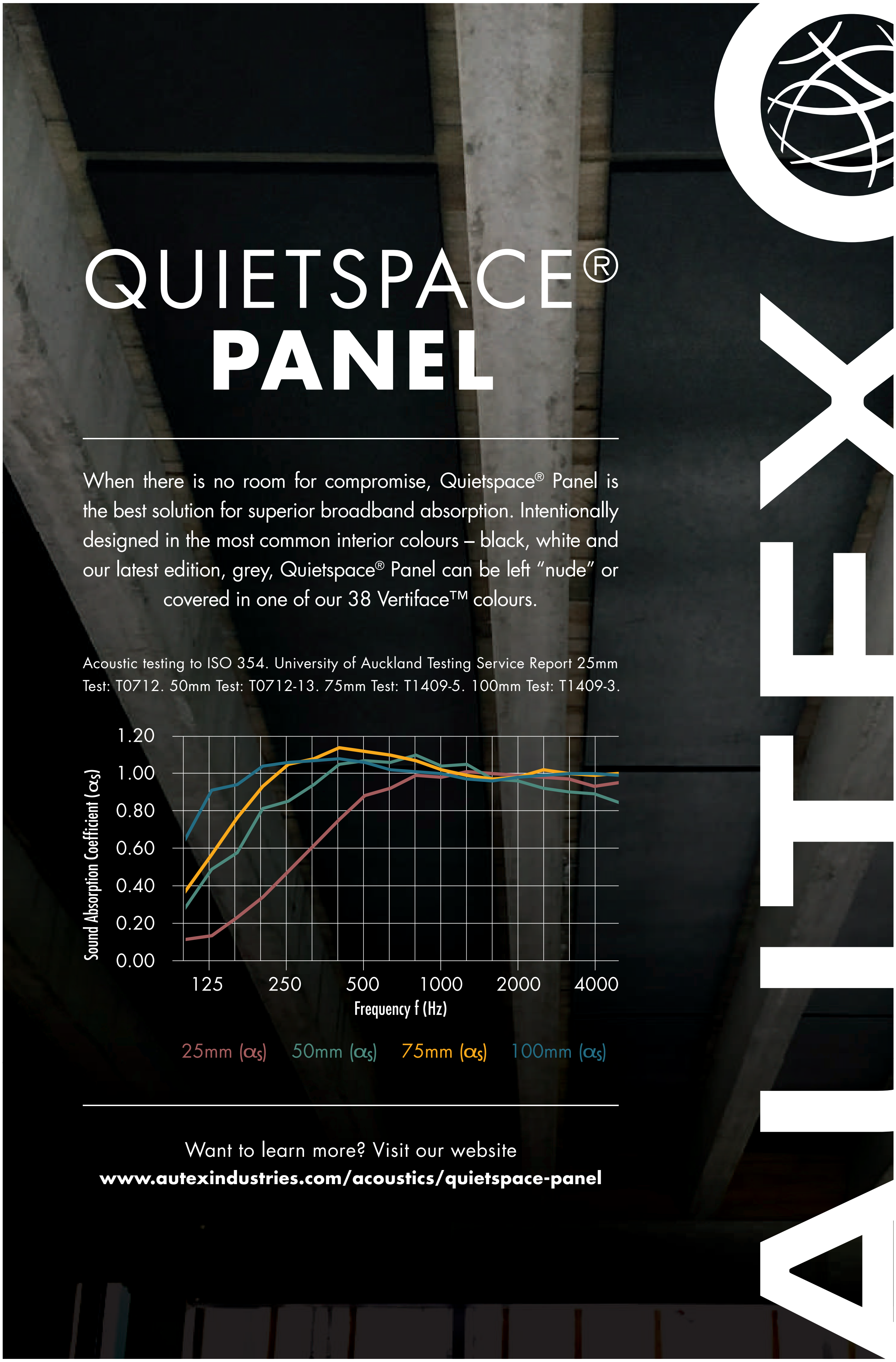
Figure 5: Type B evaluation of uncertainty

For data with estimated upper and lower limits ($x \pm a$) of uncertainty, you assume that the value can fall anywhere between with equal probability (rectangular distribution), the standard uncertainty is: $u = x/\sqrt{3}$.

For example, a sound level meter displays the measurement result of 55.5 dB. There is equal probability that the true value lies at any point in the range 54.5 dB to 56.5 dB; that is, the true measurement result is 55.5 ±1.0 dB.

The standard uncertainty is: $u = 1.0/\sqrt{3} = 0.6$ dB (to 1 decimal place). Therefore, it may be stated that the sound level meter has displayed a result of 55.5 dB with a standard uncertainty of 0.6 dB. For most practical measurements this would be regarded a s small.

It should also be noted at this point that there is often a mistake made to describe 'Type A' evaluations as 'random' and 'Type B' evaluations as 'systematic', but this is not necessarily true in all cases, and should be treated with


QUIETSPACE®
PANEL
When there is no room for compromise, Quietspace® Panel is the best solution for superior broadband absorption. Intentionally designed in the most common interior colours – black, white and our latest edition, grey, Quietspace® Panel can be left "nude" or covered in one of our 38 Vertiface™ colours.
Acoustic testing to ISO 354. University of Auckland Testing Service Report 25mm Test: T0712. 50mm Test: T0712-13. 75mm Test: T1409-5. 100mm Test: T1409-3.
Sound Absorption Coefficient (αs)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
125
250
500
1000
2000
4000
Frequency f (Hz)
25mm (αs)
50mm (αs)
75mm (αs)
100mm (αs)
Want to learn more? Visit our website
www.autexindustries.com/acoustics/quietspace-panel
AUTEX

caution (see Section 10.0 for more detail).

There are different classification methods of evaluating uncertainty components. The different terms are discussed in the following sections.

6.1 Standard uncertainty

Standard uncertainty in environmental and occupational noise measurement is the result of a measurement expressed as a standard deviation. The standard uncertainty is denoted by u. The standard uncertainty of the mean has historically also been called the standard deviation (*sd*) of the mean, or the standard error of the mean. The standard uncertainty tells us about the uncertainty of an average (not just about the spread of values). The intended purpose of u is to provide an interval about the result of a measurement.

In terms of acoustic engineering, an example of standard uncertainty could be the standard uncertainty due to the variation of weather estimated as 2.7 dB. When assessing standard uncertainty, you will always need to know the source of the uncertainty. For the example above, the source is the weather. Other sources of uncertainty include the receiver, sound path and noise source(s).

Standardisation of confidence level

Standard uncertainty equates to a 68% level of confidence (see Section 6.4 for more detail) in the measurement. All sources of uncertainty need to be expressed at the same confidence level so they can be combined together later on.

For example, a source of literature states that the total estimated accuracy of a Class 1 sound level meter is ± 1.6 dB at a 95% level of confidence (± 2 *sd*). The standard uncertainty equates to a 68% level of confidence (± 1 *sd*). Therefore, the standard uncertainty for the Class 1 sound level meter is: u = 1.6/2 = 0.8 dB.

Convert to same units

All standard uncertainty values must be expressed in the same units, so they can be combined together. So if the final value is expected to be stated in dB, then all the standard uncertainty values must be converted to dB.

For example, a source-to-receiver distance has been measured as 30 m with a standard uncertainty of ±1 m. This may be converted to dB using the inverse square law:

+1 m equates to: $10 \log_{10}(((30+1)/30)2) = +0.28$ dB

-1 m equates to: $10 \log_{10}(((30-1)/30)2) = -0.29$ dB

Because of the log scale, it produces a slightly asymmetric uncertainty interval. So approximate by taking the larger value, hence the uncertainty of ±1 m in 30 m may be considered to be the equivalent of ±0.29 dB.

6.2 Combined uncertainty

Combined standard uncertainty is the standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, that is, the combination of the individual standard uncertainties. The combined standard uncertainty is denoted by u_c. In acoustic engineering, the standard uncertainty could be the result of a measurement, when that result is obtained from the values of a number of other quantities, for example, the standard uncertainty from source, receiver and transmission path. Individual standard uncertainties (u_1, u_2,..., u_n) calculated by Type A or Type B evaluations can be combined validly by 'summation in quadrature' (also known as 'root sum of the squares'). The combined standard uncertainty for a normal distribution is:

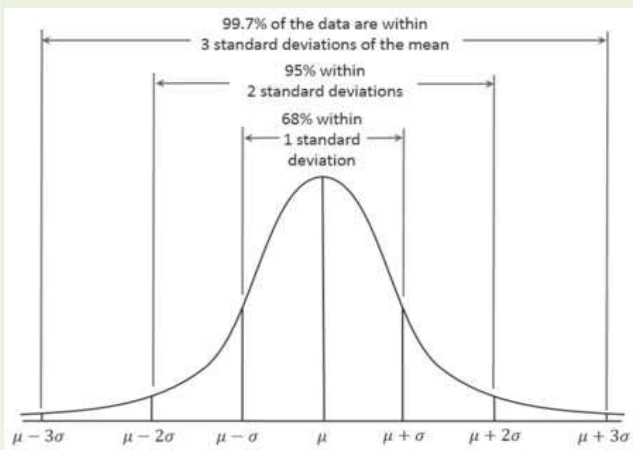
$$u_c = \sqrt{(u_1^2 + u_2^2 + u_3^2 + \ldots)}$$

6.3 Coverage factor

The *coverage factor*, k, is a numerical factor used as a *multiplier* of the combined standard uncertainty in order to obtain an expanded uncertainty. The coverage factor is stated so that the standard uncertainty of the measured quantity can be used in calculating the combined standard uncertainty of other measurement results that may depend on that quantity. The value of the coverage factor is chosen on the basis of the level of confidence (confidence level) required of the interval.

If uncertainty values are normally distributed, one standard deviation about the mean (k = 1) corresponds to a 68% confidence interval (see Figure 6 below). This is the default for all the standard uncertainty calculations so they can be pooled to produce the combined uncertainty.

Normal Distribution – "Bell Curve"



±1 standard deviation ≈ 68% confidence
±2 standard deviations ≈ 95% confidence; and
±3 standard deviations ≈ 99% confidence

Figure 6: Normal distribution and percentage confidence

One way to review the coverage factor is that once the combined standard uncertainty is calculated (which is based on one standard deviation about the mean) we can then re-scale the result to have the overall uncertainty stated at another level of confidence. Normal practice is to re-scale the combined standard uncertainty to a level of confidence of 95%.

Wherever an expanded uncertainty is quoted with a given coverage factor, you can find the standard uncertainty by the reverse process, that is, by dividing by the coverage factor.

Table 1: Different percentage confidence levels and their corresponding coverage factor

Confidence level, p (expressed as a %)	Coverage factor, *k*
68%	1
90%	1.645
95%	1.960
95.5%	2
99%	2.576
99.7%	3

The value of the coverage factor is chosen on the basis of the percentage of confidence (confidence level) that is required. The relationship between the coverage factor and the percentage confidence level (for a normal distribution) is shown in Table 1.

6.4 Expanded uncertainty

The expanded uncertainty is a quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values. It is simply the combined uncertainty multiplied by a coverage factor and produces a new confidence interval for the measurement.

Expanded uncertainty *U*, is given by multiplying the combined standard uncertainty u_c, by the chosen coverage factor, *k*:

$$U = k\, u_c$$

7. Expression of uncertainty in acoustic measurement

Correct use of noise conventions is important in acoustics so that persons using the current notation are clear on which particular noise descriptors are being used. The standard final notation for expressing uncertainty is then expressed as (value) ± *U* with a confidence level of 95%. For example, 50 ± 3 dB, with a confidence level of 95%. However, in acoustics, a host of noise descriptors are also used such as L_{A10}, L_{Aeq} and L_{AFmax} for example, which must also be factored into the notation. Thus, in acoustics, the format should be '*value-uncertainty-unit-descriptor-confidence level*'. For example, 50 ± 3 dB $L_{Aeq,15min}$ with a confidence of 95%. Note, in this example, the measurement result would normally be expressed to the nearest whole value and the confidence level to one decimal place.

8. Overview of the uncertainty process

For the purpose of acoustic measurements, the following flow chart (Figure 7) provides the general steps to evaluating the overall uncertainty of a measurement.

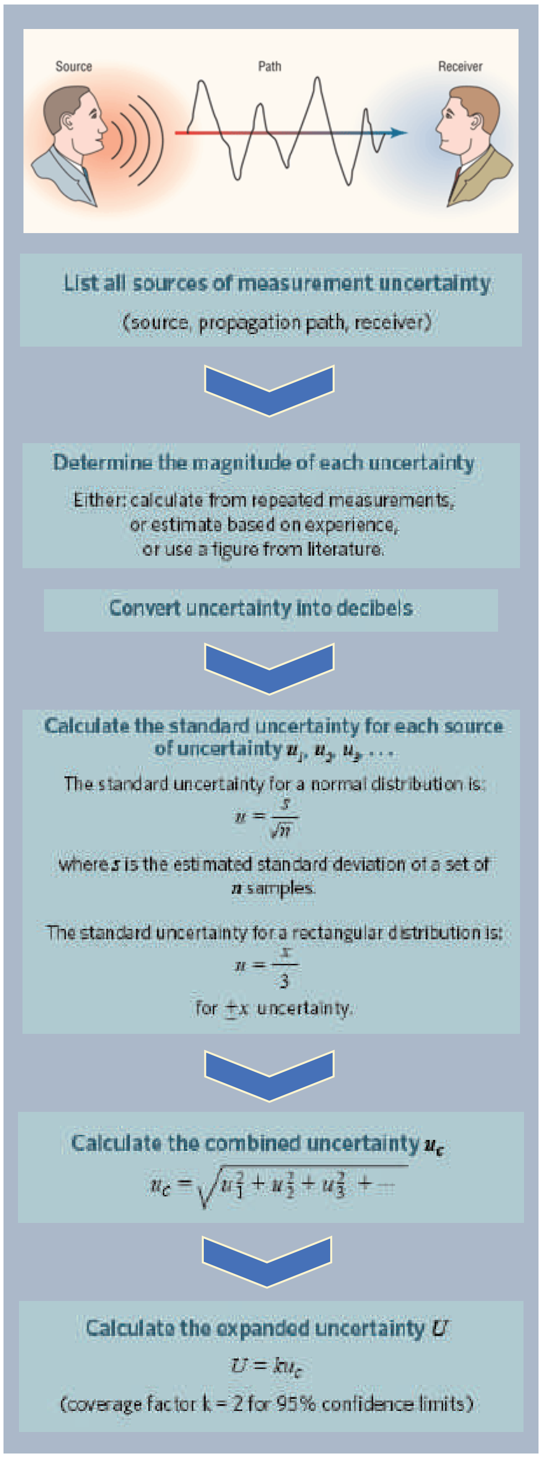


Figure 7: Flow chart of overall uncetainty evaluation

9. The Uncertainty Budget

The following two examples illustrate uncertainty budgets for the source, receiver and transmission path. The first one in Table 2 is a simple controlled scenario using a Class 1 sound level meter.

As can be seen from the table above, the greatest contribution to the uncertainty budget is the transmission path with 1.5 dB of standard uncertainty. The sound source was very stable, contributing only 0.7 dB, with a similar level of contribution from the calibrated Class 1 sound level meter. Yet overall, the expanded uncertainty is over 3 dB for this controlled scenario. If the measured value was 55 dB $L_{Aeq,15min}$, then the final expression of the result is 55 ± 3.6 dB $L_{Aeq,15min}$ with a confidence of 95%.

Table 2: Simple uncertainty budget for a controlled scenario

Source of Uncertainty	Standard uncertainty (dB)	Notes
Source	0.7	Rectangular Distribution
Transmission Path	1.5	
Receiver	0.8	Class 1 SLM
Combined uncertainty (u_c)	1.84	√(Source²+Path²+Receiver²)
Expanded uncertainty (U)	3.6	u_c x 1.96 (for 95% confidence)
±3.6 dB (at 95% confidence)		

The second scenario corresponds to a short-term environmental noise assessment using $L_{Aeq,1h}$, under favourable conditions. The uncertainty budget is shown in Table 3. The most significant contribution to the budget is the weather, and it is unlikely this can be reduced. The measured value was 52 dB $L_{Aeq,1h}$, so the final expression of the result is 52 ± 4.6 dB $L_{Aeq,1h}$ with a confidence of 95%.

It is worth noting that this level of uncertainty is the same as that reported in a number of studies involving experienced practitioners measuring the same environmental noise using their own equipment, under favourable conditions. In practice, the uncertainty may be larger for inexperienced operators and under less favourable conditions.

Without an uncertainty budget and a significant number of repeated measurements, it is not unreasonable to assume that the level of uncertainty in environmental noise measurement may be at in the order of ± 5 dB L_{Aeq}.

10. Random and systematic error

The influences that give rise to uncertainty are recognised as either random or systematic. The concept of error is an idealised concept and errors cannot be known exactly. Figure 9 illustrates the two concepts of systematic error and random error using a ‘target analogy’.

Systematic errors, are reproducible inaccuracies that are consistently in the same direction.

10.1 Random Error

A random error in measurement is caused by variability factors which vary from one measurement to another, thus a random error as the name suggests is random in

Table 3: Uncertainty budget for a more complex scenario under favourable conditions

Source of Uncertainty	Notes	Value (half-width)	Conversion of uncertainty (dB)	Distribution (divisor)	Standard Uncertainty (dB)
Source					
Location/Position	Stationary, stable	1 dB	NA	Normal (1)	1.0
Directionality	Omni-directional				
Transmission Path					
Weather	Wind direction and temperature (stable)	3 dB	NA	Rectangular (√3)	1.73
Ground	Not a major concern				
Topography	Flat – no change	none			
Receiver					
Location/Position	Uncertainty in height	0.7 dB	NA	Normal (1)	0.7
	Uncertainty in distance from source	1 in 100 m	0.09	Rectangular (√3)	0.05
Instrumentation	Class 1 with windshield	1.7 dB		Rectangular (√3)	0.98
Background	Depends on the standard		NA		
Façade effects / Reflective Surfaces	Need to make assumptions – check with small change in SLM placement			Normal (1)	
				Combined uncertainty (root sum of squares)	2.3 dB
				Expanded uncertainty (95% confidence [k = 2])	4.6 dB

nature and very difficult to predict. A good way to view random errors is to think of them as errors caused by errors that are not obvious and are variable due to chance.

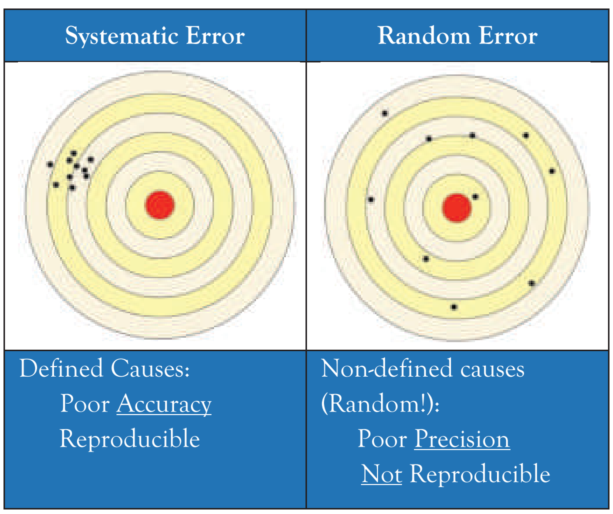


Figure 9: Systematic and random error

In acoustics, an example of a random error in measurement is the difference in noise levels due to variations in the environment. Examples include effects on the transmission path due to temperature and wind changes, or variation in the source, if it is traffic, due to varying speed and vehicle type. Also, random errors exist as a result of the instrument, even if using a Class 1 / Type 1 sound level meter, although this is very small with modern instrumentation.

Although it is not possible to compensate for the random error of a measurement result, it can usually be reduced by taking a number of repeated measurements and averaging the result.

This should have the effect of reducing the standard error of the mean. This is based on the assumption that random errors have what is referred to as 'an expected zero value', which means the errors are truly random and scattered around the mean value.

Although we expect that averaging over a large number of measurements should minimise the error, the estimate may still be imprecise, but not necessarily inaccurate. Averaging various measurements of the same quantity can help offset and reduce random errors, but can never eliminate them altogether.

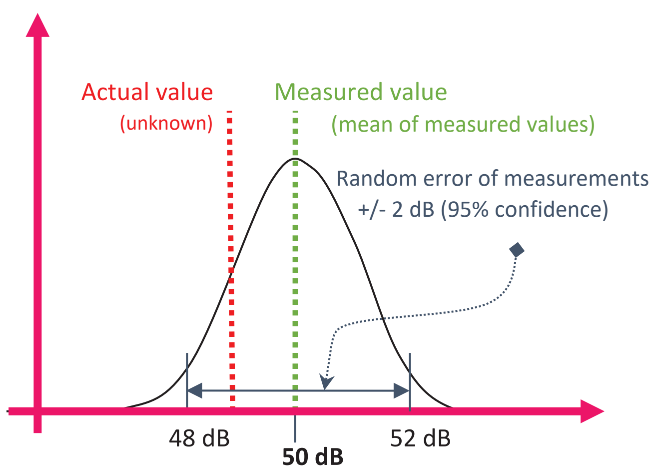


Figure 10: Random error in noise measurements

Figure 10 illustrates random error in noise measurement. For this example, the error is assumed to be randomly distributed about the mean value with an uncertainty of ±2 dB at the 95% confidence level.

10.2 Systematic Error

Systematic errors are reproducible inaccuracies that are consistently in the same direction. They are often due to a problem which persists throughout the entire measurement process. For sound level measurement, this may simply be due to the sound level meter being out of calibration by a fixed amount.

Systematic error is also referred to as '*systematic bias*'. This is errors that cannot be reduced by averaging over a large data set of measurements. A systematic error cannot be detected by analysis of the measurement data alone; some prior knowledge or observation is necessary for detection.

Figure 11 illustrates systematic error in noise measurement. For this example, the systematic error is assumed to be +1.5 dB introduced from 'drift' from the calibration levels. Thus the measured level will always be 1.5 higher than what it should be.

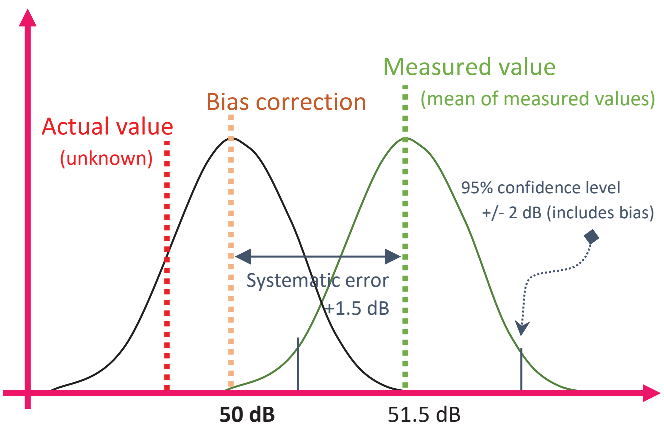


Figure 11: Systematic error in noise measurements

If this error is not accounted for by the acoustic engineer, a wrong conclusion may be drawn. Although often a very hard task, if the systematic bias can be identified and the amount determined, it can be corrected by simple subtraction of the bias.

11. The National measurement system and standards

In New Zealand, the Minster of 'Ministry of Business Innovation and Employment' (MBIE) has the primary responsibility to provide measurement standards in accordance with the International System (SI) of units. The *Measurement Standards Act* 1992 is administered by MBIE and requires the Minister to provide uniform units of measurement of physical quantities for use throughout New Zealand. The method by which this is achieved is prescribed in the *National Standards Regulations* 1976 (with relevant amendment), which requires the Chief Meteorologist of the Measurement Standards Laboratory, to be a "verifying authority" in respect of units of measurement. The New Zealand base units of measurement are required to be of the same magnitude as the standard of measurement for the time being accepted by nations adhering to the Metre Convention. A schedule of units is given in the Regulations themselves.

The value of a quantity is expressed as the product of a number and a unit. The International System of Units, the SI, is the internationally agreed basis for expressing measurements at all levels of precision and in all areas of science, technology, and human endeavour. For each kind of quantity, there is only one SI unit. The unit of sound pressure is the Pascal (Pa), which is equivalent to a Newton per square metre (N/m^2). This unit has been adopted by The General Conference on Weights and Measures CGPM and International Bureau of Weights and Measures (of which New Zealand is a member). This provides the internationally agreed reference in terms of which all other units are now defined.

There are other standards and organisations that provide information on definition and terms such as '*ISO/TR 25417:2007 Acoustics - Definitions of basic quantities and terms*'. This specifies definitions of acoustical quantities and terms used in noise measurement, including the symbols and units to be used in documentation. It was prepared by ISO Technical Committee TC 43, Acoustics, subcommittee SC 1, Noise; with the principal aim of harmonising the terminology.

12. New Zealand standards and measurement

Standards New Zealand (SNZ) is the national standards business unit within MBIE, who specialises in managing the development of standards, including acoustic standards units of measurement standards, including 'NZS 6501:1982 Units of Measurement', which provides lists of the agreed international symbols and names for the coherent units of the International System of Units, known as SI.

12.1 Current practice in New Zealand - Uncertainty and compliance assessment for environmental noise

In New Zealand, the current environmental noise standards for the measurement and assessment of environmental sound are *NZS 6801:2008 Acoustics – Measurement of Environmental Sound* (NZS6801:2008) and *NZS 6802:2008 Acoustics – Environmental Noise* (NZS6802:2008). These two standards are the corner stone of the wide-range of day-to-day environmental noise measurement and assessment in New Zealand.

The first commentary on confidence limits of measurements that is part of a NZS680X standard can be found as far back as in the 1991 version of NZS6801. In Section 6 of NZS6802:1991, *Information to be included in reports*, it states:

C6.1

A report should be objective and impartial. The report should attempt to describe the sound environment or sound scape at the time of measurement. The variation of measurements should be reported and confidence limits specified where appropriate.

However, compliance with the last part of this statement, was in the authors' experience, uncommon in noise reports of the time.

The 1999 version of this standard in Section 9 Information to be included in reports, has a similar statement, that talks about reporting variation, but not confidence limits:

C9

A report should be objective and impartial. The report should attempt to describe the soundscape at the time of measurement. Sources controlling the key descriptors should be identified. The variation in sound levels should be reported.

The 2008 version of NZS6801 and NZS6801 include some commentary on uncertainty. In the forward of NZS6801:2008, it states this topic "*would be a new issue for many users*" and that the standard "*does not require the documentation of uncertainty for all environmental sound measurements but simply encourages users to familiarise themselves with the topic through refer to a good practice guide*".

Section 9.6 of NZS6801:2008 provides a paragraph on sound measurement uncertainty, stating that "*it is recommended to record an estimate of the measurement uncertainty along with the level of confidence*" and then refers to Appendix A. However, this appendix is only *informative* meaning that it is not a technical (normative) part of the standard, and therefore does not contain any necessary requirements for conformance to the standard.

It is noted that this standard has other statements on uncertainty, in particular with respect to location information. In clause C9.4.2, it states "*Dimension uncertainty should be stated, for example ± 10 m*".

The bulk of the information on measurement uncertainty in the New Zealand standard Series NZS680X, including NZS6801 and NZS6802, appears to be from the University of Salford Good Practice Guide [5]. *Appendix A – Uncertainty*, of NZS6801:2008 provides three paragraphs on the topic, referring the reader to the University of Salford Good Practice Guide [5].

The final paragraph of Appendix A provides a key comment in regard to compliance measurements. This paragraph is reproduced in part below from the Standard.

When comparing a sound level with an applicable noise limit, the sound level should be deemed to comply if the sound level is equal to or less than the noise limit. It should be deemed not to comply if the sound level is greater than the noise limit, regardless of the uncertainty. Where compliance or non-compliance is marginal and contested, steps should be taken to reduce the uncertainty, where possible.

Section 6.6 of NZS6802:2008 refers to Appendix A of NZS6801:2008. Other references are made, such as taking three sound level measurements to reduce measurement uncertainty (see Table A3 of NZS6802:2008).

In addition to NZS6801:2008 and NZS6802:2008, the traffic noise standard, *NZS 6806:2010 Acoustics – Road traffic noise – New and altered Roads* and the wind turbine noise standard, *NZS6808:2010 Acoustics – Wind Farm Noise*, both discuss uncertainty. Section 5.4 of NZS6806:2010 provides details of uncertainty. Section 5.4.4 of NZS6806:2010 states:

When comparing a sound level with the applicable noise criteria, the sound level should be deemed to comply if the sound level is equal to or less than the noise criteria. It should be deemed not to comply if the sound level is greater than the noise criteria regardless of the uncertainty. Where compliance or non-compliance is marginal and disputed, steps should be taken to reduce the uncertainty, where possible

NZ 6806:2010 makes reference to the University of Salford Good Practice Guide. There are no supporting Appendices for uncertainty in NZS6806:2010. Like NZS6801:2008, it has an informative Appendix C on uncertainty. The Appendix C is a reproduction based directly on Appendix A of NZS6801:2008. Section 5.7 of NZS6808:2010 contains a paragraph on uncertainty stating:

Prediction and measurement of sound levels from wind farms involve values of a range of parameters that can be known or predicted only within a certain tolerance. The sizes of such uncertainties determine the level of confidence in the overall results. Information on uncertainties is provided in Appendix C.

Unlike NZS6801:2008 and NZS6808:2010, no specific comment appears to be made discussing how to deal with compliance and uncertainty. Although there are brief comments in the other NZS680X series standards, at best these are all basic operations, such as NZS6801:1999 which states under 'Section 7.2 General' that measurement uncertainty is always a factor with outdoor sound measurement and can be better quantified when sound propagation influences are defined.

13. International standards – Environmental noise

There is a host of international environmental noise standards that include addressing uncertainty in environmental noise measurement and assessment.

One such example is Chapter 4 of '*ISO 1996-2:2007 Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels*' which describes how sound pressure levels can be determined by direct measurement, by extrapolation of measurement results by means of calculation, or exclusively by calculation. Recommendations are given regarding measurement uncertainty. The standard provides the following table, which is only summarised in part as follows:

Table 1 — Overview of the measurement uncertainty for L_{Aeq}

Standard uncertainty				Combined standard uncertainty	Expanded measurement uncertainty
Due to instrumentation [a]	Due to operating conditions [b]	Due to weather and ground conditions [c]	Due to residual sound [d]	σ_t	
1,0 dB	X dB	Y dB	Z dB	$\sqrt{1{,}0^2 + X^2 + Y^2 + Z^2}$ dB	$\pm 2{,}0\ \sigma_t$ dB

[a] For IEC 61672-1:2002 class 1 instrumentation. If other instrumentation (IEC 61672-1:2002 class 2 or IEC 60651:2001/IEC 60804:2000 type 1 sound level meters) or directional microphones are used, the value will be larger.

[b] To be determined from at least three, and preferably five, measurements under repeatability conditions (the same measurement procedure, the same instruments, the same operator, the same place) and at a position where variations in meteorological conditions have little influence on the results. For long-term measurements, more measurements are required to determine the repeatability standard deviation. For road-traffic noise, some guidance on the value of X is given in 6.2.

[c] The value varies depending upon the measurement distance and the prevailing meteorological conditions. A method using a simplified meteorological window is provided in Annex A (in this case $Y = \sigma_m$). For long-term measurements, it is necessary to deal with different weather categories separately and then combined together. For short-term measurement, variations in ground conditions are small. However, for long-term measurements, these variations can add considerably to the measurement uncertainty.

[d] The value varies depending on the difference between measured total values and the residual sound.

ISO 1996-2:2007 notes that the above table is not complete as when preparing this part of the standard, insufficient information was available. What is important to note is that in most cases it will likely be appropriate to add more uncertainty contributions, thus caution is noted when applying the table. It should be noted that the 2017 3rd edition of the standard includes well over 100 mentions of the term uncertainty.

From 2015, all International Organization for Standardization (ISO) standards involving measurement (not just those to do with acoustics and noise) must include comprehensive coverage of estimating and assessing uncertainty.

14. New Zealand standards – Occupational noise

The Australian Standard AS1269 started out in 1989 with a single part titled 'Acoustics - Hearing conservation'. It was withdrawn in 1998 and replaced by a far more comprehensive five-part (0 to 4) standard on occupational noise management, which was jointly adopted by both Australia and New Zealand as AS/NZS 1269:1998. All parts of the standard were updated in 2005 and Part 4 on 'Auditory assessment' again was updated in 2014. Thus, the current five standards are:

1. AS/NZS 1269.0:2005 Occupational noise management - Overview;
2. AS/NZS 1269.1:2005 Occupational noise management - Measurement and assessment of noise immission and exposure;
3. AS/NZS 1269.2:2005 Occupational noise management - Noise control management;
4. AS/NZS 1269.3:2005 Occupational noise management - Hearing protector program;
5. AS/NZS 1269.4:2014 Occupational noise management - Auditory assessment.

All of the AS/NZS 1269 standards are generally reaffirmed by Standards New Zealand each year as the current standards. As with the NZS6801 and NZS6802, the environmental noise standards, the occupational noise standards also make reference to uncertainty but in the case of the AS/NZS 1269 standards series only very briefly. For example, AS/NZS 1269.1:2005 states in Section 8.1 that there is always uncertainty in the measurements made but does not explicitly state how this should or could be addressed.

15. International standards – Occupational noise

'*ISO 9612:2009 Acoustics - Determination of occupational noise exposure- Engineering method*', is the international standard that specifies an engineering method for measuring workers' exposure to noise in an occupational environment and the calculation of the noise exposure.

This standard provides a stepwise approach to the determination of occupational noise exposure from sound level measurements. The procedure contains steps to deal with work analysis, selection of measurement strategy, measurements, error handling and uncertainty evaluations plus calculations, and presentation of results.

The aim is to be able to compare results performed in different countries using the same method. One of the issues around uncertainty was whether or not to include this, as regulations vary across countries.

Accompanying ISO 9612:2009 are helpful tools for the end user to deal with uncertainty. These tools are included in the body of the standard and in an Appendix (normative) as well as a handy spreadsheet file. The standard states that the main sources of uncertainties and errors in the occupational noise measurement result from:

a) uncertainty due to microphone position, instrumentation and calibration – this depends on where the microphone is fixed and what class of instrumentation and calibrator is used;
b) uncertainty due to variations in the daily work, and operational conditions. Typically, this depends on the complexity of the work situation. These variations are expected to be the highest for a mobile worker among non-constant noise sources;
c) errors due to false contributions, for instance from wind or impact on microphones;
d) errors due to lacking or faulty work analysis; and
e) contributions from non-typical noise sources, speech, music (radio), public address systems, alarm signals and non-typical behaviour.

Note: c), d) and e) should be reduced by following good practice, as specified in the standard. Whereas, b) can be reduced by taking repeated measurements and averaging.

16. Acoustic modelling

The topic of accuracy in noise modelling is important as acoustic modelling is an influential tool used by acoustic engineers on a daily basis. Given the complexity of modelling and related algorithms, most modelling is done by propriety software packages. Environmental noise modelling predictions are generally used in decision making applications. The most common application of noise modelling is for noise assessments where a decision is to be made regarding some future development.

Acoustic models for environmental sound are based on statistical approximations of the real world and as such, some deviation between the predicted values and measured values may occur. Acoustic models are generally based on standards with input data being based around algorithms. However, every model has a number of uncertainties, such as meteorological conditions and path geometry, which have to be specified as modelling inputs.

There is a host of proprietary acoustic modelling software available, allowing selection of specific standards models, such as *ISO 9613-2: Acoustics – Attenuation of sound during propagation outdoors - Part 2 General method of calculation*, which is a commonly used standard for prediction software. Three popular software examples of environmental (noise) prediction software include Predictor-LimA, SoundPlan and CadnaA. Figure 12 shows an example output of sound pressure level contours from CadnaA for an industrial site.

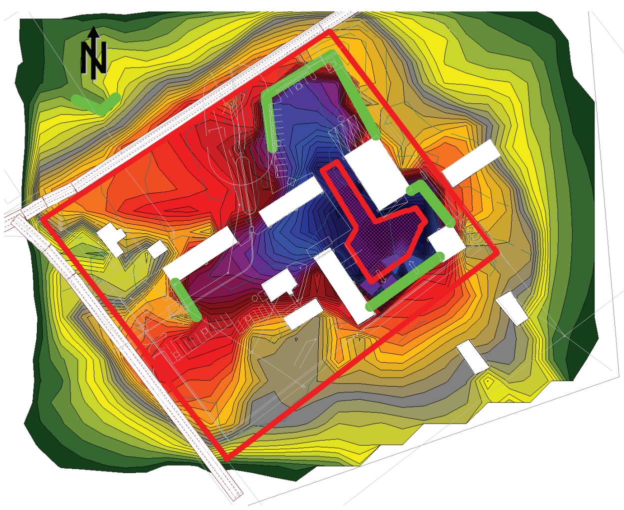


Figure 12: Example output from CadnaA

Clause 9 of ISO 9613-2:1996 provides a discussion on the accuracy and limitations of the method. It states that limiting attenuation to moderate downwind conditions of propagation will limit the effect of variable meteorological conditions to what it describes as 'reasonable values'. The standard provides an estimated accuracy of calculation of ±3 dB for distances up to 1000 m from the source. The uncertainties and challenges involved in large scale noise modelling and methodology, as opposed to modelling for smaller commercial or industrial; sites should not go unnoticed.

One of the limitations of modelling is the source to receiver distance, for example, CONCAWE [6] which was developed for receivers located between 100 m to 2000 m.

One area of noise modelling which can create significant uncertainty is whether a predicted noise level will represent the actual levels of the final development. If unknown variability or uncertainty overlap some threshold value at which different assessment outcomes are triggered, there is a significant risk of an incorrect assessment being made. Other inaccuracies relate to the limitations of the input data and to the ability of the chosen sound propagation algorithm to represent actual transmission conditions.

In summary, noise modelling is very useful and a powerful tool that should continue to be used as part of the acoustic engineers 'tool kit'. However, the question that should be asked very time, is how reliable is the noise model or more importantly, what are the qualifications and limitations of the model? This leads to the key question: what is the likely correlation between predicted levels and actual measured values

A noise model, as a tool to help decision making, represents an estimation, thus there needs to be judgement of the model's reliability and the resulting outputs. In other words, *a reliable model is one fit for purpose and the user needs to be aware of its relative benefits and limitations.* In many cases, the judgement of modelling inputs and results comes from the acoustic engineer's own experience of using the model and undertaking past field work and assessments.

17. Summary

The following sets out a summary of some issues regarding uncertainty that may be useful when undertaking future noise measurement and assessment:

- The uncertainty estimation process is not straightforward. However, even a basic appreciation of uncertainty in measurement and assessment will lead to a better understanding and confidence of reported findings;
- The area of uncertainty has become increasingly important internationally in all standards involving measurement;
- The estimation of uncertainty in acoustic measurement, assessment, modelling, analysis and reporting is an expert area. This should be carried out by an appropriately qualified and experienced person.
- A measurement or assessment result is part of a range and not a single value;
- The level of uncertainty is associated with a number of complex factors which include, but are not limited to, measurement techniques, weather conditions, instrumentation and even the experience of the person conducting the measurement;
- It is important to obtain sufficient data to properly understand and assess the effects on the measurement

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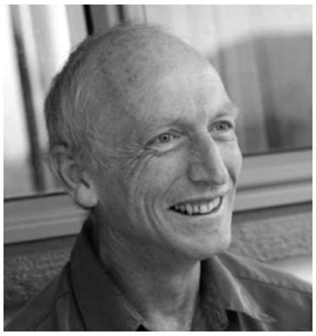
Acoustical Society of New Zealand Member Profile - Keith Ballagh



Location: Marshall Day Acoustics
Position: Principal Acoustic Engineer
Expertise: Building Acoustics
Qualifications: BE(Mech) 1st Class Honours, MASNZ

Keith is a Principal of Marshall Day Acoustics, working out of the Auckland office. Keith graduated from the University of Canterbury in 1974 with first class honours in Mechanical Engineering, before joining the Acoustics Section of the Department of Scientific and Industrial Research as a Scientist and in 1981 was appointed Section Leader. In 1981 he worked at the Physikalisch - Technische Bundersanstalt in Braunschweig, Germany. Keith is the developer of INSUL sound insulation software and Zorba sound absorption software. Both pieces of the software are used by acoustic engineers, universities and manufacturers in over 30 countries, including New Zealand. Keith is well known and respected in acoustic 'circles' throughout New Zealand as an expert in building acoustics.

Work Questions

1. **What initially drew you to the field of acoustics?** *The time I graduated (mid 70's) was a period when environmental concerns were becoming main stream, and as a young engineer the idea of working in a field to improve the acoustic environment appealed to me. Also I was into motorbikes which made a great deal of noise and finding ways of making them quieter seemed like a good idea.*
2. **What would be the principal accomplishment you have achieved in your career to date?** *I suppose the development of INSUL software has been the principal accomplishment. It's nice to think of Kiwi software being used all round the world in more than 80 Countries, and by all the principal acoustic consulting firms and many of the biggest building materials manufacturers.*
3. **What professional goals or accomplishment do you still wish to attain?** *I'd like to successfully hand over development of INSUL and our other software products to the next generation of bright young New Zealanders.*
4. **What's your definition of success in your role?** *That's easy, satisfied customers and clients, and happy staff.*
5. **Who would you describe as a role model to you in the field of acoustics and why?** *I was lucky enough to have dinner with Leo Beranek some years ago. For a man who had achieved so much in so many different fields of acoustics he was modest, charming and really lovely company. A true giant of our field.*

Personal Questions

1. **What do you like to do in your spare time?** *I have returned to a love of motorbikes (put on hold while I had kids). But this time very sedate vintage and classic bikes, nothing after 1960, and no more than 20 Horsepower (sorry 15 kW). I'm learning to weld with TIG, and a lathe and milling machine are on the shopping list.*
2. **How would you describe yourself to others in no more than a three words?** *A boring engineer.*
3. **What is your life motto or philosophy that you live by?** *I try to live by the golden rule of do unto others etc etc.*
4. **If you were a cartoon character which character would you be and why?** *Tintin (he has the best hair).*
5. **What is your favourite movie?** *Sleeping Dogs, New Zealand's first real feature length movie. Wonderfully captures a time period in New Zealand history and started Sam Neil's career.*

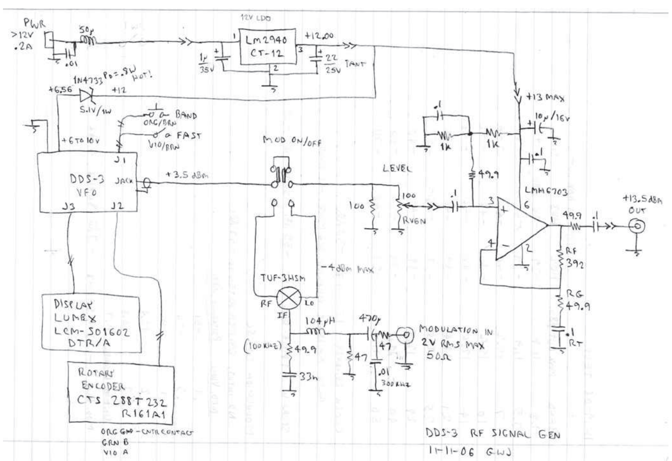
Specific Questions

1. You are well known as the 'father' of INSUL and Zorba which have become a power desktop tool used by many, including acoustic consultants and engineers worldwide. **What motivated you to develop the software and where do you see the software's future?** *Engineers are always looking at ways of predicting and calculating things in the world. Back in the day I was interested in computing and thought we could apply the power of the new personal computers to old tedious ways of calculating acoustic problems. That was a long time ago, and INSUL in particular has come a long way past those simple beginnings. I hope that INSUL can become a small part of the common and integrated tools that building designers all over the world will use in the future*

. 2. **What are the main issues and challenges you foresee for the acoustic consultants practising in NZ over the next 10 years or so?** *A tough question. In the environmental field one challenge will be to maintain a balance between complexity of analysis (given the fantastic analysis tools we now have), and the simple objective of understanding and explaining a community's response to noise. In building acoustics one challenge will be to raise the standards of sound insulation from internal and external noises while simplifying building constructions and reducing costs. An exciting new development is the use of virtual or assisted reality which will allow us to understand clients wishes much much better, but learning how to use this effectively will be a good challenge.*

Complicated and precise study into sound wave measurement – UoW

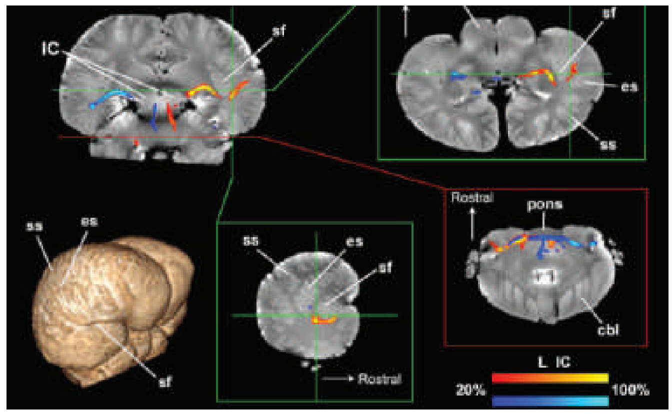
Professor Jonathan Scott from the School of Engineering at the University of Waikato has been awarded seed funding from the Science for Technological Innovation National Science Challenge to investigate methods for measuring acoustic properties.



Scott says that at present such methods "*are tiresome, frequency by frequency and on a best effort' basis*". Scott and his doctoral students are going to build an acoustic version of a vector-corrected network analyser, an AVNA. The microwave VNA is the most powerful tool available to microwave engineers. What Professor Scott is proposing involves the confluence of many technologies, including "some magnificent mathematics" he says, and with PhD student Marcus MacDonnell and their collaborator Dr John Cater at the University of Auckland they are going to make an AVNA that measures acoustic pressure waves. "*It is complicated and precise, we'll have to 3D print some of the components.*"

Breaking the brain's sound barrier

Getting sound waves through the skull and into the brain is no easy task and so to address this problem, a team of researchers has developed a ceramic skull implant through which doctors can deliver ultrasound treatments on demand and on a recurring basis.



To help doctors deliver therapeutic sound waves into the brain, the team developed and tested a transparent, ceramic material that could be used to replace a portion of the cranium and that allows easy, targeted transmission of ultrasound waves into the brain. The material, which is a new variation of the ceramic material Yttria Stabilized Zirconia (YSZ), is nonporous, allowing nonfocalized, low-intensity ultrasound waves to pass through. The implant is already in preclinical trials. The current material could be used to deliver both ultrasound and laser-based treatments.

Why a quiet life could help to reduce risk of suffering a heart attack

The cacophony of noisey town centres could trigger heart problems, according to a study which found that fluctuating sounds on busy high streets disturb normal cardiac rhythms. Researchers from Nottingham Trent University found that constant changes in noise, even at low levels, had an immediate and disruptive effect on the patterns of participants' heart rates. For the study, shoppers were asked to wear mobile body sensors to monitor their heart rates as they moved about Nottingham city centre for 45 minutes. "*We found that rapid changes in noise resulted in*

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of source variability. For example, a highly variable noise source may have greater uncertainty and require a longer measurement period;

- All measurements and assessments will always have limitations and uncertainty components. However, the overall purpose is to minimise uncertainty as well as to avoid introducing additional uncertainty (or errors) when conducting assessments;
- Uncertainty may be insignificant and inconsequential for a very clear assessment outcome, but, it may also significantly affect the assessment outcome if marginal or borderline;
- All reasonably practicable steps must be taken to reduce the level of uncertainty (and errors) by following validated assessment methods such as acoustic standards.
- If an alternative method is used or there is deviation from the validated assessment methods, such as those set out in New Zealand Acoustic Standards, state the reasons for using this method(s) and explain how this could potentially affect the assessment or findings.

18. Conclusion

It is inevitable that the next revision of various New Zealand acoustics standards will incorporate the best practice and methodology of the international standards. Since the majority of these international standards now include comprehensive coverage of estimating, handling and reporting of uncertainty, it is only a matter of time before it will become a requirement in New Zealand.

When the assessment and reporting of uncertainty becomes a requirement in New Zealand, there must be clarity about what is required in the measurement, assessment and reporting process so that technical compliance can be verified. This would, among other things, likely involve producing detailed guidelines to promote and educate a full understanding on uncertainty statements. As seen with some international standards already the development of a spreadsheet is just one such example of a possible tool to assist end users, others may include websites with step by step guidance of the user.

Qualification this review

This paper review is intended as a guide only; it is not intended to be a surrogate for any expert advice from a professional acoustic engineer. The reader and users should further understand that the information within this review does not attempt to cover all areas and applications and therefore there will be omissions. While all care has been taken in the preparation of this work and the information which is included is believed to be correct at the time of preparation, users of this paper should apply discretion and rely on their own judgment regarding the use of the above information.

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20. Acknowledgements

The authors would like to specially thank the contribution from our peer reviewers: Mr Bill Wood (Bill is an acoustic consultant at the consulting firm Marshall Day Acoustics) and Mr Vern Goodwin (Vern is employed by Southern Monitoring Services [SMS] as their Environmental Acoustics specialist supporting SMS's Environmental Noise Analysis and Advice Service contract with the Ministry of Health).

Appendix - Ontology

Metrology is defined by the International Bureau of Weights and Measures (BIPM) as "*the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology*", in lay terms meaning the scientific study of measurement.

The ontological formal naming and definition of the types, properties, and interrelationships and international vocabulary of metrology (VIM) is maintained by the Joint Committee for Guides in Metrology (JCGM), a group made up of eight international organisations (including but not limited to) International Bureau of Weights and

Measures, International Electrotechnical Commission (EC), International Organization for Standardization (ISO). In addition to the VIM vocabulary, there are definitions given in ISO and IEC standards, for example.

<u>The following provides some basic definitions for terms used in this review.</u>

Measurand: Quantity intended to be measured.

Uncertainty (VIM - the vocabulary of metrology definition): Non-negative parameter characterising the dispersion of the quantity values being attributed to a measurand, based on the information used. This VIM definition remains very similar to the definition of the standard deviation. This is why the GUM (ISO, 2008a) provides a more specific definition, with 3 notes

Uncertainty (GUM - Guide to the Expression of Uncertainty in Measurement definition): Parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand.

Note 1: The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

Note 2: Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

Note 3: It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

True value: Quantity value consistent with the definition of a quantity. A true value is usually unknown.

Measurement Accuracy: Closeness of agreement between a measured quantity value and a "true" quantity value of a measurand.

Measurement Precision: Closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions.

Measurement Error: Measured quantity value minus a reference quantity value.

Systematic Error: Component of measurement error that in replicate measurements remains constant or varies in a predictable manner.

Random Error: Component of measurement error that in replicate measurements varies in an unpredictable manner.

Repeatability: Condition of measurement, out of a set of conditions that includes the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time.

Reproducibility: Condition of measurement, out of a set of conditions that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects. Measurement reproducibility is measurement precision under reproducibility conditions of measurement.

Standard uncertainty: Measurement uncertainty expressed as a standard deviation.

Combined uncertainty: Standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model.

Expanded uncertainty: Expanded uncertainty product of a combined standard measurement uncertainty and a factor larger than the number one.

Coverage Interval: Interval containing the set of true quantity values of a measurand with a stated probability, based on the information available.

Coverage Factor: Number larger than one by which a combined standard measurement uncertainty is multiplied to obtain an expanded measurement uncertainty.

We have several decisions to bring you for this last issue for 2017. A cost decision relating to the re-consent of the Gebbies Pass turbine, Banks Peninsula, which while not specifically about acoustics is none the less interesting in the award given to the appellant. This is followed by two decisions involving acoustic issues forming part of the assessment of effects for two different proposal, a community wind turbine in Otago and a quarry operation near Christchurch.

Following is a summary of the proceeding but a full copy of the decision and the final conditions of consent can be found on the RMA Net website at: www.rma.net

In the Environment Court

LUKE PICKERING – Appellant

CHRISTCHURCH CITY COUNCIL – Respondent

[2017] NZEnvC 119, 10p, [37] paras; 9 August 2017

Costs Decision

Luke Pickering sought costs of $19,226.62 against the Council and Windflow Technology Ltd in relation to an unsuccessful appeal concerning the renewal of consent for the operation of the Gebbies Pass wind turbine, Banks Peninsula. The Court noted the appeal was not unsuccessful as conditions of consent were tightened and Mr Pickering's conduct was that of a responsible litigant. The Court found that Windflow failed to adequately explore the possibility of settlement, where compromise could have been reasonable expected, thus the Court was satisfied there were grounds to exercise its discretion and ordered costs against Windflow of $10,815.00.

The Court also found that the Council failed to make independent enquiry into the actual sound experience of the noise for the local valley residents and its reliance on expert evidence that the effect of noise below the guideline levels in the Standard was acceptable was flawed. As such the Court held the Council was to pay the sum of $3.605.00 to Mr Pickering.

In the Environment Court

BLUESKIN ENERGY LIMITED – Appellant

DUNEDIN CITY COUNCIL – Respondent

[2017] NZEnvC 150, 92p [356] paras; 11 September 2017

Summary of Facts

The local community of Blueskin Bay set up a Trust in 2008 to facilitate a positive, healthy, secure and resilient future for the bay and linked communities. One of the initiatives was to develop local electricity production and Blueskin Energy Ltd was formed and originally applied for consent to construct and operate three wind turbines on Porteous Hill, Blueskin Bay. The Council rejected the application and Blueskin appealed with a substantially modified proposal for a single taller wind turbine. This was known as a "community turbine" and the Trust's decision-making process was guided by the assumption the community would prefer a visual reminder of how it was meeting its consumption needs which led to the Trust pursuing sites that would be visible from within Blueskin Bay. The final location on Porteous Hill was held to be most suitable due to: good road access, close to the 33kv local network; wind quality; and because of the impact on the landscape. However, the Council still supported its decision and declined consent.

The modified proposal for a single turbine was a non-complying activity under the operative Plan and while Blueskin agreed the effects would be more than minor, it held that the proposal was supported by the National Policy Statement (NPS), was not contrary to the objectives and policies of the Plan and as such should be considered under s104 RMA. The Court discussed the NPS but held that it did not mandate the grant of consent or there would be no need for the decision-maker to recognise the benefits of the activity.

The Court detailed the receiving environment, and concluded that Porteous Hill contributed to and was an important component of the attractive rural setting of Blueskin Bay. Giving an overview of the planning context, the Court noted that in the operative Plan consideration had to be given to the maintenance and enhancement of the amenity values associated with the rural character of the area. The proposed Plan also detailed an appropriate location for a turbine was one which would avoid significant adverse effect on visual amenity and character. The Court found that where the seascape was in the foreground view, the adverse effect on landscape and amenity values would be significant. Due to the height of the turbine relative to the hill it would become the focal point in the landscape. The Court did note however that the effect of the turbine would lessen when the seascape was not in view. The turbine would have adverse visual effects and effects on the amenity of three dwellings located close to the turbine.

Assessment of the acoustic environment near the turbine was hampered by vandalism of the monitoring anemometers and as such there was a lack of wind data and background sound level detail. NZS 6808 was agreed between experts as the appropriate standard for assessing effects of noise levels from the proposed turbine, although the experts disputed the noise limit which should apply. After assessing the noise evidence, the Court held that turbine noise, if audible during the daytime would be at an acceptable level with the presence of other anthropogenic noises from farming activities and the state highway. At night, the potential for sleep disruption was also found to be highly unlikely both at low and high wind speeds. However, the Court noted comprehensive background sound measurements had yet to be undertaken and there was a wide range between the highest and lowest measured sound level at each residence.

The maximum difference between the lowest measured sound level and the predicted turbine sound level was about 9dB at low wind speeds and about 15dB at high wind speeds. Given the level of uncertainty in those differences and the potential for adverse effects from audible turbine noise on the aural amenity of the nearest residents in the evenings, as a condition of consent, the turbine was to be shut down from 7pm to 10pm each evening over the summer months. Lastly the court held that the noise limits to be applied should be those recommended by the respondent's expert which advocated for specific limits at the notional boundaries of each dwelling within the vicinity of the turbine.

Overall the Court accepted that the proposal would have wider benefits for the community but the change would adversely affect the quality of the coastal landscape and would not maintain (or enhance) the amenity values associated with the character of the rural area for the Porteous Hill residents. The Court held there were significant adverse landscape and visual effects and the effects on existing amenity were not mitigated. On the evidence, the Court was not satisfied that the landscape's values should stand aside for the benefits of the proposal. As such it was the Court's judgement overall that the granting of consent would not promote the purposes of the Act.

Costs held:
Appeal declined and costs reserved

In the Environment Court

YALDHURST QUARRIES JOINT ACTION GROUP – Appellant

CHRISTCHURCH CITY COUNCIL – Respondent

HAREWOOD GRAVELS LIMITED – Applicant

[2017] NZEnvC 165, 89p [315] paras; 11 October 2017

Summary of Facts

Yaldhurst Quarries Joint Action Group, a group of residents within the immediate locality, appealed the grant of consent for Harewood Gravels Ltd to establish a gravel quarry and associated earthworks at 21 Conservators Rd, McLeans Island. Over the last three years the Christchurch City and Canterbury Regional Councils had granted several applications for quarry activities which, if all developed, would encompass 300 hectares of land within a 2.5 km west-east arc of the proposed quarry site. The residents were concerned with the cumulative adverse effects of the quarrying on their health and their existing amenity.

The site was located within the Rural Waimakariri Zone, where quarrying was a discretionary activity, however the application overall was non-complying due to the proposal exceeding the relevant noise standard at the site's southern boundary by more than 10 dB, where the predicted noise level was 76 dB L_{Aeq}. The key issue in the proceeding was whether the adverse effects of the proposed quarry, either considered by itself or together with the other quarries in the locality, were consistent with the rural working environment. The Court asked two questions;

A) Were the adverse effects of the proposed quarry on the environment minor?

B) Was the application contrary to the objectives and policies of the District Plan?

The Court detailed the planning context and discussed the receiving environment, the proposal's benefits and the existing rural character and amenity, before assessing the visual effects of the proposed activity and the effects on existing amenity focussing on noise, dust, traffic and vibration. After assessing the evidence, the Court was not satisfied that the effects of the proposed quarry would be minor. For those adverse effects of which the Court was

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Uncertainties in Acoustics

Norm Broner

Broner Consulting Pty Ltd, Melbourne, Australia

Abstract

In acoustics, we are often required to demonstrate compliance with a given criterion. The criteria may be specified in a Regulation or a specification. When acoustic measurements are conducted to demonstrate compliance, there needs to be a consideration of the uncertainties of measurement and there needs to be an understanding of what the criterion is requiring as well as an understanding of what you are measuring. For example, when measuring environmental noise to check compliance with an EPA criterion, is the case that the actual criterion level must never be exceeded or can it be exceeded by some amount for say 50% of the time. If you measure a noise level of 50.1 dBA when the criterion is nominally 50 dBA, is this really a fail or is it still a pass? In this paper, some of these complexities are explored primarily using the VIC EPA SEPP N-1 Regulation as an example.

Originally published in the Proceedings of ACOUSTICS 2016

1. Introduction

The ISO Guide to the Expression of Uncertainty in Measurement defines uncertainty of measurement as the parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

- The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.
- Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. The other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.
- It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

The uncertainty has a probabilistic basis and reflects incomplete knowledge of the quantity. In acoustics, this uncertainty can be due to differences between instrumentation and calibration and, if measuring environmental noise, due to season, weather, temperature inversions, locations for the monitoring, reflections, standing waves and interference and the impact of ambient sound.

If a consultant was to repeat a measurement in nominally similar conditions, say 5 times over 5 days, then we would have a measure of repeatability. It is likely that the result would be within a standard deviation of the mean value.

If a number of acoustic consultants were able to measure the same sound under the same circumstances using their own instrumentation, it is very likely that the result would be around a similar but not necessarily identical mean but with more variability. So we also have the concept of reproducibility.

Given the uncertainty in our measurements then, what number do we use to determine compliance with a noise Regulation? Does the Regulation indeed tell us what level is required for compliance?

For example, we all know about various criteria for industrial noise, for traffic noise and for train noise. Invariably, there will be a specific decibel level prescribed for a given time period. In some instances, the criterion level is derived based on a measurement of the existing ambient noise level in some form e.g. the Victorian EPA State Environment Protection Policy No N-1 (N1) requires the measurement of the hourly L_{A90} values for the day, evening and night periods and this is used to determine the appropriate Noise Limit. However, the process of determining the Limit is somewhat undefined and open to interpretation so that different consultants will get different answers.

Similarly, the NSW Industrial Noise Policy requires the measurement of the L_{A90} in 15 minute samples for each period, then describes the process to derive a *rating background noise level* (RBL) that provides a single figure that represents the background noise level for assessment purposes. Note that the current NSW Draft states "*The objective of carrying out long-term background noise monitoring at a location is to determine existing background noise levels that are indicative of levels during the entire year*". However, the NSW Draft does not specify how long "*long term monitoring*" is.

Depending on the length of time, the answer might differ by a decibel or two: whilst this is not a lot necessarily in background noise level terms, it may have a big impact in terms of compliance and thus with respect to the cost to achieve compliance. A similar question can be raised with respect to the requirement by the Queensland EHP that the proponent "*Describe the results of any baseline monitoring of noise and vibration in the proposed vicinity of the project, including long-term measured background noise levels that take into account seasonal variations*" whatever "*taking into account*" means!

In addition, when a Regulation or Policy prescribes a criterion Limit to be achieved for compliance, does that mean that the criterion Limit level is never to be exceeded or can it be exceeded for say 10% of the time or 20% of the time? And when we measure the noise level at a given location, is it the mean of the measured noise level that is to be compared with the criterion Limit or is the mean plus a number of standard deviations? And how many measurements should a consultant conduct to determine the noise level at the location being investigated? One, three, five? Over how many weeks, seasons?

2. Background noise level

In the State of Victoria, Schedule C1 in N1 sets out the requirement for measurement of the background noise level. The hourly background noise level needs to be determined for the day, evening and period periods and in Sub Clause 4, N1 states that "*the background level shall be rounded to the nearest decibel*". Is this rounding to be up or down? Further, Sub Clause 5, N1 requires that the background level be measured during "*dry conditions with low to calm winds*" but these conditions are nowhere defined. So it is left up to the consultant to decide and there is inherently a level of uncertainty in the result.

In order to set the Noise Limits, it is necessary to know whether the background noise level is neutral or not (Schedule1 B1 and B3 of N1).

To determine whether the background noise level is neutral for a given period, Schedule C2 requires "*at least two measurements of the L_{A90} each of at least 5 minutes' duration and arithmetically averaged to obtain a representative measure of the background level for the period*". However, when should these samples be measured and what is meant by a "*representative measure*" is not defined.

Figure 1 below shows the measurement result for a location near a main thoroughfare. Looking at the diurnal level L_{A90} variations, where would you choose your two 5 minute samples so as to be representative? What would you do for the sample shown in Figure 2?

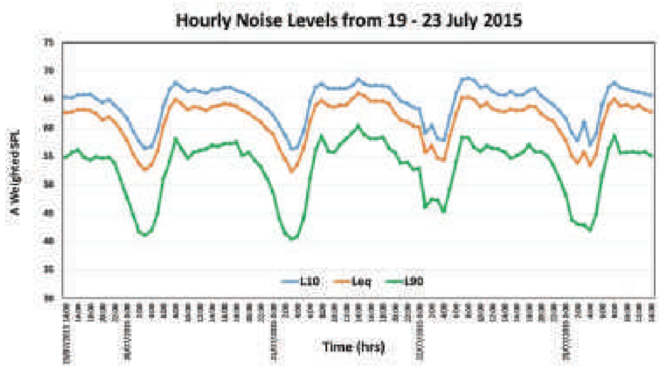

Figure 1: Noise Levels Measured During A Survey in July 2015

So how do you know what is the absolute background noise level and how close to that level do you need to be with your average? This result can have a very important impact on the final derived Noise Limit and thus on the costs to comply with that limit. The consideration of the level of uncertainty in this result is thus very important.

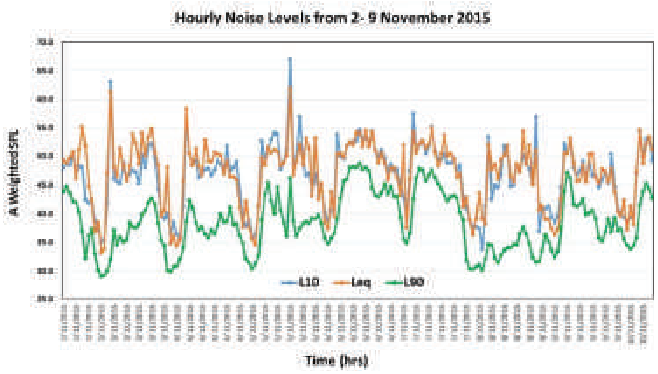

Figure 2: Noise Levels Measured During the Survey in November 2015

Table 1 below shows the arithmetic average of the hourly background noise levels for the day, evening and night time periods for a given location over a one-week period. N1 does not state how many measurements need to be made. It can be seen that the values vary considerably across the week of the measurements. The lowest measured value is highlighted for each period and was used as a basis for determining the period Noise Limit.

Table 1: Overall background noise levels measured during each time period

Date (2014)	Day (0700–1800 hrs)	Evening (1800–200 hrs)	Night (2200–0700 hrs)
7th July	50.6*	**48.6**	40.3
8th July	49.2	48.9	40.9
9th July	52.3	49.6	41.6
10th July	52.7	50.0	38.8
11th July	52.9	52.6	39.0
12th July	50.6	50.6	33.4
13th July	**47.5**	51.7	**29.3**
14th July	48.9*		

**Incomplete measurement periods*

It is quite clear that had only one or two measurements been conducted, that a very different result would have been obtained. But is a week period representative or should the measurement be over 2 or 4 weeks? And is it necessary to repeat this measurement during the Summer season to see if the results are similar? And is choosing the **lowest** period average over a 7-day period an appropriate selection or is this result penalising the industry under investigation?

3. The effective noise level

Part V Clause 15 of the N1 states that where noise emissions "*exceed the requirements*", then steps shall be taken to reduce the level to, or below, the relevant Policy noise limits. In Schedule A Clause 6 Atmospheric Effects, N1 states that "*When the effective noise level may be significantly affected by atmospheric effects*" (two key words here are not defined – "*may*" and "*significant*"), a derived point may be used located near to the industry (again "*may*" and "*near*" are not defined). "*Where it is inappropriate to use a derived point because the of the size of the industry or the unavailability of an alternative measurement point, three measurements shall be taken within a 30-day period at the noise sensitive area. The effective noise level shall be the arithmetic average of the three measurements*". In this latter sentence, the "*size*" that makes the derived point inappropriate is not explained nor is the "*unavailability*" explored. So that these are open to interpretation and different consultants could get different answers as a result.

Further, in the instance when three measurements are taken within a month, can these three measurements be taken on consecutive days? Or do they need to be spread out at say one a week? The EPA stated to the Author that they consider this requirement to mean that the measurements should be conducted to achieve the 80% level, i.e. not the highest level that might occur but rather one that would occur 80% of the time. In essence, this is a recognition that the highest level might not be representative of the noise emission. But the Regulation does not define clearly what this measurement protocol is so there is an uncertainty in the result that is raised. Again, the impact on an industry could be very important with respect to cost to achieve compliance.

4. Uncertainty in noise level

The Author often sees noise level measurements quoted with more than one digit past the decimal point e.g. 73.36 dBA. This example has 4 significant digits but is it legitimate to claim such accuracy as implied by having two digits after the decimal point? This implies that the real number is in the range 73.356 to 73.364. In practice, you would be lucky to be able to claim accuracy to the tenth place (ie one digit after the decimal point). For the example above, this would be 73.4 dBA. More likely is that you can only claim accuracy to the units place. For the example above, this would be 73 dBA.

In determining the uncertainty of a measured noise level, you need to consider the uncertainty associated with the measurement equipment. This is likely to small, of the order of say 0.1 dB. Then you need to consider the uncertainty related to the measurement conditions. If you repeated the measurement a number of times, you would get an indication of the mean and standard deviation and you could determine the confidence level of the result.

Figure 3 shows a normal distribution and the range for two confidence limits. For a normal distribution, the 95% confidence interval is within +/- 1.96 standard deviations of the Mean and the 99.73% limits are within 3 times the standard deviation.

For most cases of environmental noise level measurement, an expanded uncertainty of +/- 3 dBA representing a coverage factor of 2 is reasonable. This represents a confidence interval of 95%, one can have 95% confidence that the result is within 3 dBA of the measured value.

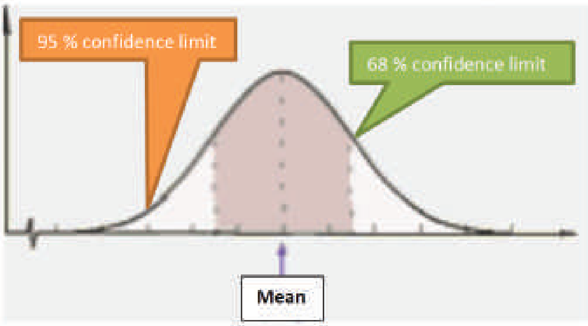

Figure 3: Normal distribution showing the mean and the shaded areas representing +/- 1 standard deviation about the mean (For a normal distribution, ± *u* encompasses about 68% of the distribution)

5. Compliance

So if the measure value has an uncertainty attached, how is compliance demonstrated? For example, if the Noise Limit was 73 dBA and the measured value was 73 +/- 3 dBA, would this be considered a pass? If uncertainty is not considered, then clearly this measured level could be considered a pass. But if the uncertainty is considered, then does that require that the measured value be say 70 dBA for a pass or maybe 71.5 dBA would be required for compliance. Most Regulations/Guidelines do not explain what the requirement on the measurand needs to be and what uncertainty is required in making an assessment.

It is necessary for the Regulation or Guideline to define what is required for compliance. Should it be that the mean measured noise level not exceed the Noise Limit ever or should it be that the mean plus either 2 or 3 standard deviations not exceed the Limit? In order for an assessment of compliance to be made, clearly some statement about uncertainty is required.

5. Predicting compliance

Table 2 shows a calculation of the predicted internal noise level in a room in a hospital due to a helicopter landing on a helipad nearby. The calculation shows the incident noise level, the noise reduction of the tested façade, and area and room corrections to arrive at an overall internal noise level of 69 dB L_{AFmax}, which is claimed to be well below the 75 dB L_{AFmax} criterion.

As can be seen, the noise source level is shown with one figure after the decimal point. For example, the 250 Hz octave band level is shown as 102.0 dB. This implies that this octave band source level is between 101.05 and 102.04 dB. But we know that the uncertainty in the incident noise level can be at least +/- 3–10 dB depending on which octave band you are dealing with. Similarly, there are uncertainties associated with each line in the calculation. When taking into account the different uncertainties which are additive, compliance is seen to be not as straight forward and not necessarily achieved. What was previously a predicted noise level well below the criterion is now only just within the criterion!

Table 2: Prediction of Internal Noise Level (dB) - due to a helicopter

	Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Over-all
Source Noise Level at the Facade	103.0	105.0	102.0	101.0	96.0	92.0	85.0	82.0	102
Vision Facade Performance (Laboratory Tested)	-28.1	-25.9	-35.7	-41.2	-42.9	-47.4	-57.2	-59.0	
Area Correction	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	
Room Absorption Correction	-5.5	-6.4	-7.3	-8.2	-9.1	-10.0	-10.9	-11.8	
Resulting Noise Level	**79.7**	**83 .0**	**69.3**	**61.9**	**54.3**	**44.9**	**27.2**	**21.5**	**69**

Based on the resulting of calculations for the vision and non-vision areas of the facade compliance with the 75 dB L_{Amax} noise level criteria will be achieved.

Table 3 shows the revised calculation and the statement of compliance (U_{95} in the table represents the 95% confidence level uncertainty).

Table 3: Prediction of internal noise level (dB) - due to a helicopter and uncertainty

	Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Over-all
Source noise level at the facade	103	105	102	101	96	92	85	82	102
Vision facade performance (Lab Tested)	-28	-26	-36	-41	-43	-47	-57	-59	
Area correction	10	10	10	10	10	10	10	10	
Room Absorption correction	-6	-6	-7	-8	-91	-10	-11	-12	
Resulting noise level	**78**	**83**	**69**	**62**	**54**	**45**	**27**	**22**	**69**
Uncertainty U_{95}, dB (2sf) {Info only}	5	4	3	3	3	3	3	3	
Uncertainty U_{95}, dB (1sf)	6	5	4	4	4	4	4	4	
Sample noise level + U_{95}	86	88	73	66	58	49	31	26	73
Criterion (dB)									75
Design complies?									Yes

The above table shows that in accounting for design uncertainty, there is a 95% probability the true value under the scenario assessed will be within 5 dB of the result, I.e. 97.5% probability it will be less than 73 dB and 99.2% probability it will be less than 75 dB.

7. Conclusion

The issue of uncertainty in acoustics has generally not been considered but is becoming more recognised as

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Acoustics Quiz

Q1 What, if any, is the difference between the acoustical properties of a 'Dissipative Muffler' and a 'Reactive Muffler'?

Q2 Explain the difference between noise immission and noise emission.

Q3 Define the following anonyms and abbreviations: 1. ANSI; 2 WHO; 3. ISO; 4 I-INCE; and 5. CONCAWE?

Q4 True or False, 'annoyance' in terms of noise can only be quantified subjectively?

Q5 True or False, the Pinna is also known as the external ear?

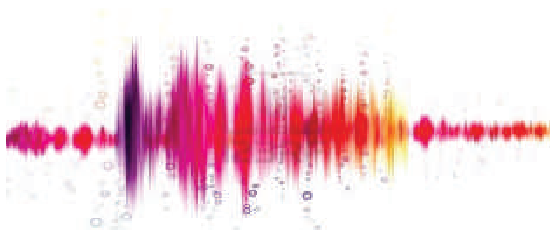
Q6 Define what 'Empirical acoustic modelling' means.

Q7 What is beamforming?

Q8 Briefly define Young's Modulus.

Q9 True or False, there is no difference in the speed of sound at sea level versus the speed of sound at high altitude?

Q10 True or False, the total sound pressure level at a receiver decreases by about 3 dB per doubling of distance for a line source?



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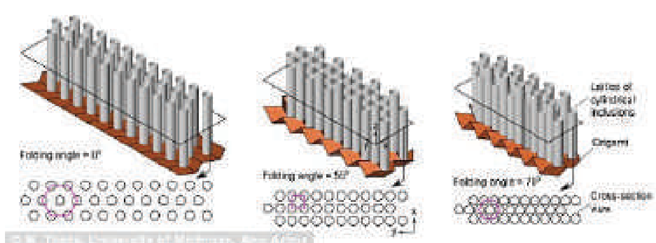
rapid disturbance to the normal rhythm of participants' hearts," said researcher Dr Eiman Kanjo of Nottingham Trent's School of Science and Technology. For more information refer to the research which was published in the journal Information Fusion.

Kapiti Expressway lose rumble strips

The $630 million Kapiti Expressway is to lose half its rumble strips in an effort to placate sleep-deprived residents. The raised strips on the left-hand lanes will be removed in each direction of the 18-kilometre road, after costing about $7500 a kilometre to install.

The righthand strips, alongside the median barrier, will remain. Nick Fisher, of the Expressway Noise Action Group, said the work would go some way to helping noise-affected residents get a good night's sleep. Kapiti Coast Mayor K Gurunathan said he felt sorry for everyone involved, but was concerned that removing the lines could endanger lives. NZTA was "bending over backwards to help" and was "caught between a rock and a hard place" as it tried to keep motorists safe and remedy noise complaints, Mayor K Gurunathan said.

A New 'Origami Sonic' traffic noise barrier

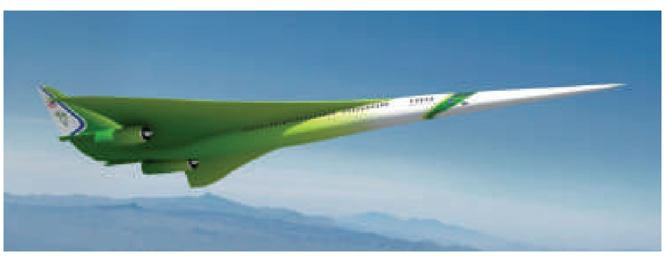


Managing traffic noise has been a challenge for acoustic engineers for some time, largely because different types of vehicles produce a broad range of sounds frequencies on

roads. At present, generally only massive concrete wall-like barriers can effectively dampen all of these various sounds. However, researchers have developed a new method, dubbed the 'origami lattice' prototype, that could potentially reduce acoustic noise on roadways.

The origami sonic barriers rely on cylinders called inclusions which are placed on an aluminium sheet bent into a Miura fold - an origami folding method which involves folding a flat surface, such as a piece of paper, into a small area - like an accordion. As the resulting lattice folds, the cylinders are drawn closer together or farther apart, diffusing noise in different frequency ranges. The engineers designed an origami lattice prototype as an adaptive structure that selectively muffles noise. Unlike periodic sound barriers with inclusions of fixed design, the new lattice system can be manipulated and might enable adjustments to target specific frequency ranges. Heavier vehicles produce noise at lower frequencies than lighter vehicles, and cars traveling quickly during off-peak times skew toward higher frequencies than cars stuck in traffic jams.

NASA's Supersonic jet designed to reduce sonic boom



It has been reported that NASAs is working on a new supersonic passenger jet X-PLANE project (photo above), which some people are calling the "new Concorde." The aircraft, which could fly people between London and New York City in three hours, is designed to be quieter than past supersonic jets and creates a sonic "heartbeat" rather than a sonic "boom." It has been reported that researchers at NASA are working to define a new standard for lessening sonic booms, and success would remove one hurdle to the return of supersonic commercial aircraft. It has also been reported that NASA is working to create new experimental aircraft that will demonstrate new "green aviation" technology intended to dramatically reduce fuel use, emissions and noise – with the goal of cutting emissions from the nation's commercial aircraft fleet by more than 50 percent, while also reducing perceived noise levels near airports to one-half the level of the quietest aircraft flying today (photo below).

Nelson Airport expansion watchdog group raises concerns on noise

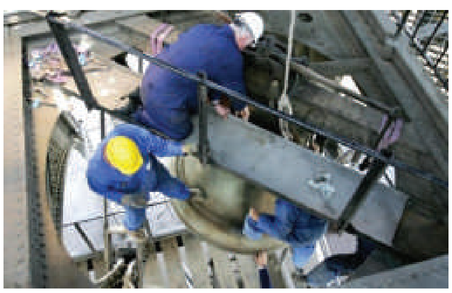
The Nelson Mail has reports that a group of residents who live near Nelson Airport are concerned that it might also bring more noise. The Nelson Airport Noise Action Council known as 'NANAC' is calling on the airport company and the Nelson City Council to consider its concerns regarding noise as the new terminal building and car park take shape. The group is taking aim at noise rules in the Nelson Regional Management Plan (RMP), which is under review. NANAC has made submissions to the council in an attempt to tighten up noise regulations at the airport. Former NANAC chair David Brathwaite said the group was not so concerned about regular airplane noise, rather the increase in "industrial noise" from aircraft maintenance during the night and compass configuration.

Nelson Airport CEO Rob Evans said the expansion plans,

which include a new terminal building, flight tower and car park, were not expected to result in increased noise. There's no impact on noise whatsoever." However, he did say that increased capacity at the airport could result in an increase in the number of flights over time. "Clearly there's increased flights coming now so the construction is to cater for that growth we're currently experiencing and provide for a bit of growth into the future." Evans said the airport had to operate within the rules set out in the RMP.

Big Ben's bongs could sound different after tower repairs

The Telegraph has reported that acoustic experts have stated that the distinctive bongs of Big Ben could be altered after its refurbishment. Britain's well known bell will soon fall silent for several months as part of a three year £29 million revamp, to repair the Elizabeth Tower and clock. Officials have warned that the tower clock is in such a 'chronic state' that it may fail if work is not carried out urgently. Experts at the University of Leicester who have recently carried out laser vibration mapping to find out how the 13.5 tonne bell produces its characteristic sound, say that renovation work could alter the frequency of sound waves, and length of the bong.



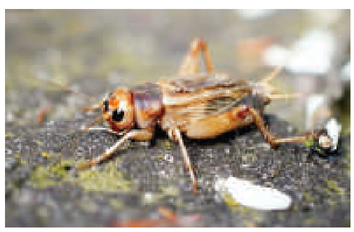
Experts have said that removing accumulated soot or making new repairs to the crack in the bell may change its tone, while plans to renovate the structure of the tower, which include refitting the frame which holds the bell, could impact how long the bong travels for. Big Ben has also never been tuned, so restorers may take the opportunity to make the bell sound closer to what was originally intended. When it was originally fitted by Whitechapel Bell Foundry the clapper was too large, causing a crack to appear and leading to its peculiar dissonant sound. Consequently, it has not rung true since 1859.

South Island Branch Meeting

On the 26th of September, the South Island Branch of the ASNZ had their second get-together of the year. Held at Engineers Bar (fitting name), it was both a good catch-up and informative. The South Island branch of the ASNZ would like to thank all who attended.

Mysterious sonic weapon?

The Daily Mail has reported that in August, American and Canadian diplomats working in Havana reported hearing sounds that were believed to be a mysterious sonic weapon. Doctors termed the sounds '*directional acoustic phenomena*', and even noticed brain changes in those hearing it.



But Cuban scientists insist that a sonic weapon was not to blame. Instead, they suggest that the sound was produced by the stress of listening to '*noisy crickets*' in Havana. A report issued by a board of Cuban scientists suggests that crickets are the unlikely culprits of the brain-changing sounds.

While US officials did not provide sound recordings to the scientists, Carlos Barcelo Perez, an

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satisfied on the evidence that it could reach a view on the level of additive effect, in each case the Court found the effect would be "more than minor", and in relation to the direct effect of traffic noise on residents located at two properties, the effects would be significant.

The Court held that the applicant had not discharged its persuasive burden and provided evidence from which the Court, with any level of confidence, could reliably make predictions about the future dust environment and the rural character. For the purposes of s104D the Court was unable to determine whether the application was contrary to the objectives and policies. It was not satisfied the evidence established to the required standard that the use and development of rural land would support and maintain the amenity values of the rural environment.

Court held:

Appeal upheld and grant of consent refused.

Costs reserved.

Disclaimer - *This article has been provided to help raise an initial awareness of some recent cases involving acoustic issues. It does not purport to be a full listing of all decisions which have acoustic issues, nor does it replace proper professional advice.*

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a consideration in measurement and assessment of compliance. The Regulations/Specifications need to be clear about what exactly they require in this regard so that compliance can be clearly demonstrated. Whilst Regulators want a noise level below a fixed limit, the level of confidence of a measurement needs to be indicated and considered when assessing compliance. In addition, the criteria need to explicitly state what is required in terms of uncertainty.

References

1. ISO Guide 98-3 Uncertainty of Measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)
2. State Environment Protection Policy No N-1 "Control of Noise From Commerce, Industry and Trade"
3. NSW Draft Industrial Noise Guideline http://www.epa.nsw.gov.au/resources/epa/150185-draft-industrial-noise-guide.pdf
4. Queensland EIS Information Guideline http://www.ehp.qld.gov.au/management/impact-assessment/eis-processes/documents/generic-tor-supporting-guidelines/tor-guideline-noise-vibration.docx Uncertainty of Measurement Results http://physics.nist.gov/cuu/Uncertainty/glossary.html Rounding and Significant Digits http://www.purplemath.com/modules/rounding2.htm

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environmental physicist at the National Institute of Hygiene, Epidemiology and Microbiology, recorded evening sounds around the residences. The recordings revealed that the biggest noisemakers were insects.

In particular, he found that the Jamaican field cricket chirps at a frequency matching the sound on the recordings, which measured around 74 dB. It follows recent news that medical experts have discovered changes in the brains of US and Canadian diplomats, which fuelled growing scepticism that some kind of sonic weapon was involved. Medical testing revealed the embassy workers developed changes to the white matter tracts. These regions act like information highways between brain cells letting different parts of the brain communicate. Dr Joel Moskowitz, a community health professor at the University of California, Berkeley, said: '*This makes me think the victims may have developed electromagnetic hypersensitivity (EHS) from exposure to electromagnetic fields in the embassy*'.

Train in pain - Are noise-filled carriages bad for your health?

The Guardian has reported that seven years is the minimum prison sentence that should apply to people on UK public transport who listen to music through their phone speakers (also known as "*sodcasting*") with two years for banal phone conversations that never end. For many, the news that South Western Railways is thinking of

getting rid of quiet carriages will not be music to their ears. Some people think quietness is overrated. They can focus come what may: screaming babies; thumping house music; people texting with keyboard clicks. Why do some of us need quiet but others don't? Is the world getting quieter or louder?

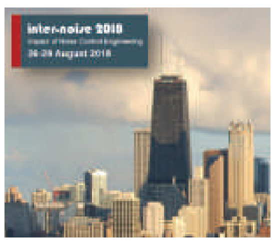
Psychotherapist and writer Philippa Perry suggests that we are becoming frightened of quietness, possibly as a result of technology. "*Blocking out the quiet seemed to start with transistor radios, then Sony Walkmans, so that your whole life – if you wanted – could have a soundtrack. You'd walk in the crowd with your earphones on and feel like you were the star of your own movie.*" The healthiest type of noise, Perry suggests, could be the back-to-basics crunch of leaves underfoot; birds singing; the patter of raindrops. Nature. Or anything soothing. Certainly not Despacito on the bus during rush hour.

2018

7-9 May, Ibiza Spain. NOVEM (Noise and Vibration Emerging Methods) 2018
http://novem2018.sciencesconf.org

7-11 May: Minneapolis, USA, 175th Meeting of the Acoustical Society of America
www.acousticalsociety.org

27-31 May: Heraklion, Crete, Greece , EURONOISE 2018
. www.euracoustics.org/events/eaa-conferences



26-29 August: Chicago, USA, 47th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2018)
www.i-ince.org

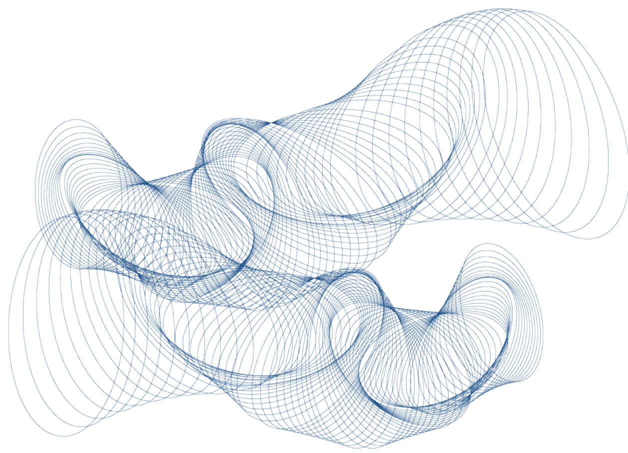
5-9 November: Victoria, Canada, 176th Meeting of the Acoustical Society of America
www.acousticalsociety.org

2019

13-17 May, Louisville, Kentucky, USA. 177th Meeting of the Acoustical Society of America
www.acousticalsociety.org

09-12 June 2019, Madrid, Spain. 48th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2019) 177th Meeting of the Acoustical Society of America
www.acousticalsociety.org

08-13 September 2019, Aachen, Germany. 23rd International Congress on Acoustics (ICA 2019)
www.ica2019.org



Answers

To the Ten Question Quiz (on page ??)

A1 A Dissipative Muffler is a muffler for which its acoustical performance is determined chiefly by the presence of sound-absorption materials (i.e. flow resistive material) whereas the acoustic performance of a Reactive Muffler is determined chiefly by its geometrical shape

A2 Sound emitted by a source[s] is noise emission and sound heard by an observer is noise immission. Noise immission is always dependent on the environment in which the sources are located. For environmental sound outdoors noise immission levels can be influenced by the nature of the terrain, sound absorption by the ground, and wind and temperature gradients — among many other effects.

A3 ANSI = American National Standards Institute. WHO = World Health Organization. ISO = International Organization for Standardization. I-INCE = International Institute of Noise Control Engineering. CONCAWE = CONCAWE, CONServation of Clean Air and Water in Europe.

A4 False. Annoyance to noise is a person's internal response to a noise. Although annoyance can be quantified psychologically as a subjective rating it can also be quantified objectively / technically by a physical noise descriptor, for example, the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$).

A5 True. The pinna is the external ear which gives rise to multiple reflections and resonances within it. These effects and the location of the pinna on the side of the head make the response of the pinna directionally variable to incident sound in the frequency range of approximately 3 kHz and above.

A6 Empirical acoustic modeling refers to any kind of modelling (including computer) based on empirical observations rather than on mathematically describable relationships of the system being modelled. Empirical knowledge is received by means of sense and particular observation and experiment.

A7 Beamforming measures the amplitude and phase of the sound pressure over a planar or spherical or linear array of many microphones and this is used to maximise the total summed output of the array for sound coming from a specified direction, while minimising the response due to sound coming from different directions

A8 Young's Modulus, also known as the elastic modulus, is a measure of the stiffness of a (solid) material.

A9 False. There is a difference in the speed of sound at sea level vs. at altitude i.e. at sea level the speed of sound is approximately 340 m/s (based on 15°C ambient temp) while at altitude say 11,000m above sea level the speed of sound is approx 295 m/s (based on -57°C ambient temperature). Note, density and pressure decrease 'smoothly' with altitude, but temperature does not. However, the speed of sound can increase with height in two specific regions of the stratosphere and thermosphere, due to heating effects in these regions.

A10 True. For a line source the noise level decreases by 3 dB per doubling of distance.

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Publication Dates and Deadlines

New Zealand Acoustics aims for at least three issues per year, in April, August and December.

The deadline for material for inclusion in the journal is the 1st of each publication month, although long articles should ideally be received at least 4 weeks prior to this.

Advertising

Enquiries regarding advertising are welcome. For a list of current prices and any further information please contact: advertising@acoustics.org.nz

Society Membership

Associate Membership of the Acoustical Society of New Zealand is open to anybody interested in acoustics. Members receive benefits including:

- Direct notification of upcoming local events
- Regular mailing of Noise News International
- Reduced charges for local and national Society events
- Priority space allocation for trade stands at Society events
- Discounted rates on selected acoustic products

To join the Society, visit www.acoustics.org.nz or contact the Secretary: secretary@acoustics.org.nz