

## **A Review of Current Long-term Environmental Sound Level Measurement Technologies**

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Long-term environmental sound level measurements have emerged as an essential tool for governmental agencies, communities, airports, industrial facilities, and acoustical consultants. Recent improvements in digital signal processing, distributed power, wireless communications, and compressed audio recordings have enabled a new generation of smart, portable sound level measurement devices. These technologies have been incorporated to different degrees in instrumentation offerings from various manufacturers. This paper presents a critical review of the commercially available equipment from major manufacturers, and compares the capabilities and technologies implemented by each. Also discussed are future technology improvements, novel audio recording and power hardware, case studies, and recommendations for those specifying and evaluating this type of equipment.

## **A Novel Method to Measure the Absorption Coefficient of Outdoor Plane Surfaces Using Sound Pressure Levels at Two Positions**

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A novel method is presented for measuring the *in-situ* sound absorption coefficient of plane surfaces outdoors. The impetus for investigating this method arose from a perceived oversimplification in ASTM Standard E 966, "Standard Guide for Field Measurements of Airborne Sound Insulation of Building Facades and Façade Elements". That standard applies a correction of -6 dB or -3 dB for sound pressure levels measured flush with the exterior of the façade, or at a distance of 2 metres from the façade, respectively, implying coherent and non-coherent wave addition respectively at those two positions. Those corrections implicitly assume that the façade material is a perfect reflector (an absorption coefficient of zero). Conversely though, if the façade were fully absorptive, the sound pressure levels measured flush with the façade and at 2 metres would not differ at all from the free field measurement, so the corrections of -6 dB and -3 dB would not apply. Therefore, for a façade with a non-zero absorption coefficient, the method in Standard E 966 tends to underestimate the sound insulation. However, using the physical setup from Standard E 966 as a basis, this paper demonstrates how the simple sound-level difference between a pair locations, one flush with the façade and one at 2 metres from the façade can be used to compute the *in-situ* sound absorption coefficient. The result can be used either as a more accurate basis for measuring sound insulation of façade elements, or simply to quantify the absorption of an outdoor plane surface.

## **PEEKING INSIDE NOISE BY “SEEING” TONE**

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Tone quality, while a critically important concept in the music world, is largely inaccessible through the science of acoustics. This is due to the interpretive nature of tone and its dependence on personal taste, experience, cultural and social environments. Scientifically speaking, the problem centres around the non-stationary behaviour (both transient and continuous) of the sound spectrum and temporal components of musical tone. Interestingly, these are the same characteristics that make noise analysis and control so challenging. This paper proposes a method for detecting non-stationary components of musical tone and non-steady state noise usually invisible to conventional means of sound analysis.

Specifically, the method presented here was used to identify the differences in the tone of the French Horn created by different acoustically reflective surfaces placed in the near field of the horn bell. The fundamentals of the analysis method using the Haar function wavelet are explained and results are shown that demonstrate the effect of two different kinds of sound reflectors.

## **Noise Management Information System: an integrated approach**

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For more than four decades Brüel & Kjaer has been a main supplier of systems for environmental noise management and monitoring. More than 200 major installations on all continents have been made, including some of the world's largest airports.

An integrated approach to environmental noise management has the potential to make this task more effective through the sharing and reuse of data, optimisation of noise management activities and prevention of new problems arising. An integrated environmental noise management system, comprising the latest technology, can cover complaints, mapping, monitoring, calculations and abatement, and provide reports, public information and safe, intuitive archival of data, results, reports and analyses.

Being modular and scalable, individual components such as calculation software or individual noise monitoring terminals can be purchased and used individually. Data can be exchanged, where deemed useful, and, over time, as needs arise, the system can be expanded, within budget limits, to an increasing number of tasks and with improved efficiency.

The central part of the Brüel & Kjaer Noise Management Concept is Noise Management Software Type 7843A (installed on Noise Management Server Type 3642), which was developed with the future needs of environmental noise management in mind. The software has been designed using the latest design methods and the modern software architecture makes Type 7843 A a solid platform for the continued evolution of the Brüel & Kjaer Noise Management Concept.

As a modular solution, the concept is also suitable for handling multiple clients/areas and smaller tasks such as semi-permanent monitoring of a concert and allows data exchange between different users and between consultants and clients.

The paper will describe some possibilities offered by the integrated solution

## **Reverse Engineering: the use of noise measurements for calculation of noise maps principles**

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When calculating environmental noise, verification/calibration of the calculated contours is crucial, particularly when implementing a source emission database in a new area such as a new country. Measurements are also important in the analysis of the dynamic behaviour of noise levels, e.g. daily, weekly and monthly variations and to follow the long term development in noise levels. Therefore, an easy interaction between measured and calculated environmental noise values is important – this is known as the Environmental Noise Management Concept.

In order to apply corrections to emission models, reverse engineering techniques are used. Measurements are made under specified conditions. Correcting the noise emission models using reverse engineering was highlighted by the comparison of the noise map results (obtained by calculation only) with real measured values. However, it is important to correctly compare the measurement and calculation values to ensure that they represent the same parameters. For example, corrections to the desired parameter due to individual microphone positions may be desirable.

Guidelines for the selection of suitable measurement positions, of a measurement strategy, how to combine the values from noise measurements and calculations, and the assessment of results are required. These do not, at this moment, exist. This paper, based on theoretical studies and practical experiences, provides input to such guidelines and describes:

- Temporal sampling
- Spatial sampling
- Correction of measured levels to reference values for comparison with calculations
- Documentation of changes made to the mode

## **DESIGN OF AN ACOUSTIC SPREAD SPECTRUM SIGNAL FOR THE STUDY OF OUTDOOR NOISE PROPAGATION.**

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The design of an acoustic spread spectrum signal for the study of outdoor sound propagation is described. The acoustic spread spectrum signal consists of a frequency carrier biphase-modulated by a specially-designed pseudo-random code sequence. This so-called "Inner and Outer" code sequence is specially designed for simultaneous fine time resolution and large range ambiguity. Experiments measurements are presented to demonstrate the correlation properties of the Inner and Outer code. The results illustrate that the Inner and Outer sequence, when used as an acoustic spreading code, can provide significantly improved ways of measuring sound propagation outdoors. In particular, speeds of sound calculated from precise times of flight measured from the cross-correlation of recorded acoustic spread spectrum signals are compared with measurements from sonic anemometers. The fine time resolution for time of flight suggests an application in acoustic tomography, with particular relevance to the study of turbulence structures in the atmospheric surface layer. [Work supported by EPSRC UK]

## **A METHOD FOR VERY FINE FREQUENCY IDENTIFICATION AND AN UNUSUAL APPLICATION**

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In order to identify sources of pure tones, and to assess and confirm the presence of a low-frequency noise problem, it is very useful to be able to determine the frequency of a signal very specifically. Usually this is done in 1/3 octave bands, but for critical source identification, 1/12 octave analysis, or Fast Fourier Transform (FFT) techniques are used.

The software in some instruments have incorporated algorithms which “correct” the frequency resolution by a factor of 10, where the exact frequency of a pure tone lies between two frequencies (or lines) from an FFT measurement. For a recent project, which dealt with frequencies in the infrasonic (less than 20 Hz) range, this correction increased the resolution of the specification of a pure tone (vibration) frequency from 0.3 Hz to 0.03 Hz.

The project involved the re-certification of a bridge which is supported by tension members (called “Dywidags”). In order to assess the tension in each of these members, the individual members were excited into lateral motion, and the tension derived from the measurement of the lateral frequency of each dywidag (similar in concept to the vibration of a guitar string).

## **NEW TECHNIQUES FOR LONG-TERM RECORDINGS OF ENVIRONMENTAL NOISE**

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In 1993, the technique of using long-term audio recordings was first used in Alberta. These recordings have generally used Hi-Fi Video-Cassette Recorders (VCR). With the availability of 10 hour VHS cassette tapes, this method allowed continuous recordings over an entire nighttime period (while allowing the field personnel a decent night’s sleep). The built-in recording of a time identifier on the taped recording allowed rapid and accurate access to periods of interest. This method has been very useful. In recent times, HI-Fi VCR’s, with features which allow manual set-up, have become very difficult to obtain, and the 10-hour tapes have become more difficult to obtain. Rumours indicate that companies intend to quit making VCRs entirely. Therefore, as existing equipment wears out, there is a quest for alternative methods which provide long-term recordings with adequate quality.

This paper looks at the recent use of portable electronic recording devices which can record either in WAV or MP3 formats. Within the 2 GB file size limit imposed by the Windows operating systems, continuous good quality recordings of 50 hours or more can be obtained. With appropriate software, these unmanageably large files can be broken into smaller files, which can be more easily used for source identification. I have found it most useful to break the original recording into samples of one-hour duration, split so that each subfile covers one ordinal hour. These allow the easy identification of time-specific events.

**HOW WINDY IS MY BACKYARD?  
ON THE USE OF PORTABLE WEATHER MONITORING STATIONS FOR  
NOISE MONITORING**

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Equipment used for conducting environmental noise monitorings is more elaborate than ever before with the ability to collect large amounts of data on the noise levels. Coupled with the ability to conduct simultaneous digital audio recordings, the Acoustical Engineer has the ability to very accurately discern the noise climate in the area monitored. Generally, the missing component is useful weather data that is specific to the monitoring area. Equipment used for this must be portable, battery powered, and capable of relatively accurate results. This paper will discuss portable weather monitoring stations for use in the field in conjunction with noise monitoring stations, the applicability to noise data analysis, and the relative level of accuracy compared to full scale weather monitoring stations.

**Drilling Rig Noise Assessment  
Model vs. Field Monitoring Results  
Imperial Oil Resources  
Cold Lake In-situ Bitumen Development Area**

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During the 2006 Imperial Oil Resources (IOR) in-situ bitumen-drilling program, Cold Lake Projects (CLP) identified the need to assess drilling noise in relation to stakeholder receptor sites. This paper reviews the results of previous drilling rig noise measurements as well as the results of IOR's Cold Lake predictive modelling results (e.g., 1996 drilling rig measurements and the predicted noise results obtained from the IOR, Cold Lake noise model January, 2006) with noise monitoring conducted at two operating drill rigs during June, 2006. Sound level measurements at the U08 & U09 operating drill rigs were completed at distances of 5m, 10m, 20m and 40m and the measurements were used to calculate Sound Power Levels (PWLs) for the drilling floor. These results were compared with the 1996 PWLs, which provided similar results but with a change in the dominant contributor. The 2006 results reflect higher PWL values due to equipment noise being centered at the drilling complex as opposed to the rig floor in 1996. The 2006 field monitoring results (drilling rig and existing Cold Lake operations) were then used by HFP to update the predictive model which was provided to IOR in January, 2006. This paper summarizes these results and provides additional information and considerations in the determination of operational drill rig noise in relation to stakeholder receptor sites and compliance with the Alberta Energy and Utilities Board (EUB) Noise Control Directive 38.

## **Characterization of Sound Emitted by Wind Machines**

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Wind machines are tall, fixed-in-place, engine-driven propeller fans that pull warm air down from high above ground during a strong thermal inversion, raising air temperatures around cold-sensitive crops such as grapes and tender fruits. They help protect crops from cold-injury that can affect the following year's crop and long-term plant health. Wind machines are typically used three times during; winter's extreme cold temperatures; spring's late frosts; and autumn's early frosts. These machines are vital to the viability of the ice wine grape growing regions as they use the prevailing temperature inversion conditions during very cold (-20 C) and still winter conditions to create an opportunity to take warmer (-15 C) upper atmosphere air and blow toward the ground where the grapes are growing. The temperature gradient that is created is sufficient to spare the life of the grape. There are currently some 300+ wind machines in the Niagara area and the number is eventually expected to grow to 1000+. Noise complaints have multiplied as the number of wind machines have increased. A long term applied research project commenced in late 2005 to establish best environmental management practices so the use of wind machines would be limited to those times when absolutely needed to protect crops from damage. One part of this project included a sound study which examined the acoustic emission characteristics, the sonic differences of units made by different manufacturers, sound propagation properties under 'typical use' atmospheric conditions and low frequency noise impact potential.

## **Meteorological Effects on Sound Propagation**

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Sound level modeling is usually based on algorithms that assume that the atmosphere is near standard. Some sophisticated models include adjustments that account for downwind or atmospheric stability class. However, sound propagation under strong atmospheric inversions is not consistent with standard algorithms. Therefore, modeling methods tend to underestimate the sound levels at distant receptors under these exceptional conditions. One result of nonstandard propagation is that sound levels from a specific source may be significantly increased at some distant locations. While the conditions that produce the nonstandard propagation might be infrequent, they can be responsible for tension between industrial noise sources and neighboring communities.

The purpose of this paper is to summarize the various effects on sound propagation during conditions of nonstandard atmospheric conditions. These may include radiation inversions, frontal patterns or downwind conditions. The paper summarizes various atmospheric structures and the corresponding noise propagation conditions. Several case studies will be presented where nonstandard noise propagation challenged the characterization and treatment of industrial noise problems. These cases have raised questions about the frequency and intensity of the nonstandard noise propagation. The paper also investigates weather forecast products that may aid in identifying areas that are prone to such atmospheric conditions.

## **MODELING OF INTERIOR NOISE IN LARGE COMBUSTION TURBINE POWER STATIONS**

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The interior noise environment in large power generation stations is characterized by a complicated interaction between many uncorrelated noise sources, reverberant effects, and near-field sound levels close to large structures and enclosures. From an occupational exposure perspective, Canadian, US, and EU requirements are often met by restricting unprotected access to areas with excessive noise. Thus it is desirable to map the distribution of noise inside the turbine hall and other mechanical areas. While this is often accomplished after the fact by direct measurement of the noise contours, analytical methods can be used in the plant design process to minimize the high noise areas or shift them to little traveled areas of the plant.

Conventional exterior noise propagation software may be used, with some caution, to model the distribution of noise indoors, including the near-field. The ray tracing algorithms inherent in such software is well suited to the cramped and complicated interiors commonly found inside power stations. Once the initial model has been built, it may be used to conceptually arrange equipment and enclosures for reduced noise exposure. Potential sources of error, the initial validation process, and estimation of enclosure effectiveness are discussed. A comparison is made with the results of auditorium acoustic software, which while designed for interior problems may not be as suitable in predicting industrial noise.