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New techniques to determine specific noise for increasing the effectiveness of continuous unattended noise monitoring systems

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ABSTRACT

Continuous, unattended noise monitoring systems can immediately alert you should noise levels exceed defined criteria. Once alerted to an exceedance, operators can act to return levels to compliance. This approach has two significant limitations. Firstly the operator can only take action after the breach has occurred and therefore systems are only able to inform owners about problems that have occurred in the past, rather than allowing them to maintain compliance. Secondly the noise limit exceedances might not be due to specific noise from the operator but from unrelated, residual noise in the often complex noise climates around the site. Compliance breaches are frequently triggered by aircraft overflights, road traffic or community sources. Modern monitoring systems enable users to view noise characteristics and listen to the noise breach to determine the source and take action if it is relevant. However, this approach can create significant false positives each taking up operator time to address. This paper describes how airport noise management systems have addressed this problem by combining data from other systems. It also shows how different techniques are required in urban & industrial noise management, giving examples of techniques that allow operators to take action before a compliance breach occurs.

Keywords: Environmental noise management, monitoring, compliance
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1. THE NEED - DETERMINING SPECIFIC NOISE

Noise legislation is typically based on the assessment of noise from a specific source against legal limits (1). Noise limit exceedances might not be due to specific noise from the operator but from unrelated, residual noise in the often complex noise climates around the site. Compliance breaches are frequently triggered by aircraft overflights, road traffic or community sources.

It is difficult to separate specific sound from residual sound (1) with manned measurements. When continuous, unattended noise monitoring is mandated, this becomes an even bigger challenge as there is no operator present on-site to note causes. However, using additional technology and automation offers additional opportunities not always available with manned measurements.

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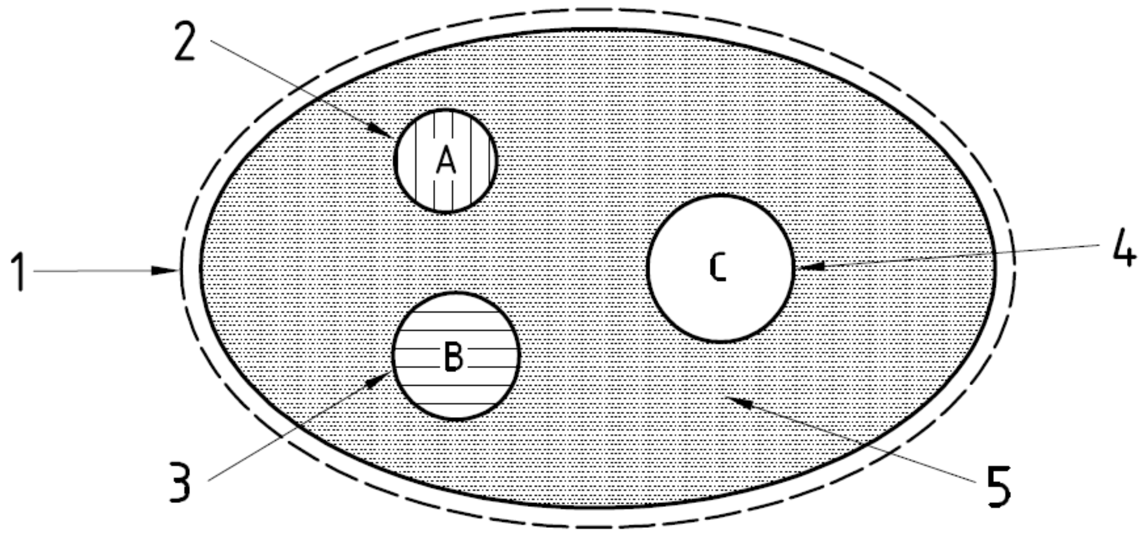


Figure 1 – Three specific sounds under consideration (2, 3, 4), the residual sound (5) and the total sound (1). Source. ISO 1996-1:2003

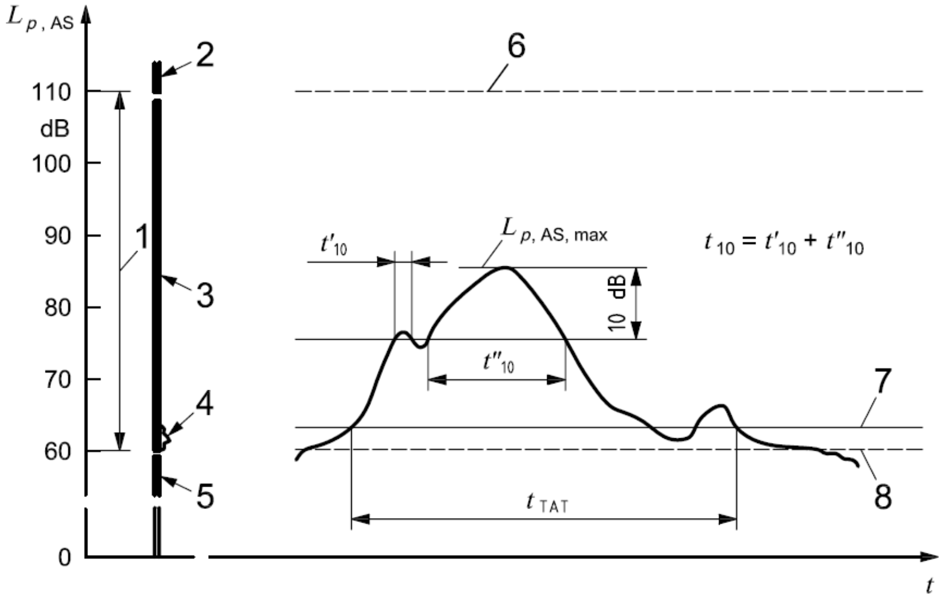
Unattended systems need to pick out noise sources that are relevant. Thus, intelligence is added to better identify sources and reject irrelevant sources.

2. EARLY DEVELOPMENTS IN CONTINUOUS UNATTENDED NOISE MONITORING SYSTEMS

Airports have long been the driving force behind continuous unattended noise monitoring for several decades. So much so that standards have been developed. ISO 20906 (2) from 2009 is the latest international standard in this area. Airport noise monitoring has developed on event detection based systems as the specific noise is short-duration and thus quite-well suited to this approach, in particular when data transfer from monitoring terminals was difficult and expensive, resulting in the need for data reduction.

The initial approach was to use noise events which look at the broad band noise envelope. This works because noise from commercial aircraft has a certain duration, around 10-20 seconds, which distinguishes it from road traffic, for example, which is much shorter.

A sound event is detected when, for example, the sound level exceeds a threshold level by at least a specified amount for a specified range of durations and, importantly, when an event terminates, the sound level does not rise again above a specified level within a specified time (see Figure 1).



Key

$L_{p,AS}$	AS-weighted sound pressure level	1	primary indicator range / dynamic range
$L_{p,AS,max}$	maximum AS-weighted sound pressure level	2	overload range
t	time	3	range considered
t_{10}	10 dB down time	4	disregarded range
t_{TAT}	time above threshold	5	non-transmitted range
		6	upper limit of primary indicator range / dynamic range
		7	threshold level
		8	lower limit of linear operating range

Figure 2 – Noise event detection. Source. ISO 20906:2009

In most cases, the measurement of the sound pressure is integrated over the duration of the aircraft event. To enhance reproducibility, the event level requires the integration of the sound pressure in at least the range above the level “10 dB less than $L_{p,AS,Max}$”. However, this requires that the event is significantly above the residual sound. In ISO 20906, for an acoustically reliable measurement, the aircraft event should be clearly distinguishable from residual sound, i.e. the difference between the level of the background sound and the sound level at the onset of a measurement should be at least 5 dB. This places restrictions on the location of noise monitors to sites where the maximum sound pressure levels, $L_{p,AS,Max}$, of aircraft events are at least 15 dB greater than the level of the average residual sound. This technique is implemented in a wide range of commercial solutions such as Brüel & Kjær’s Noise Monitoring Terminal Type 3639 (3).

Enhancements on the above include using floating threshold levels for the event triggers rather than absolute levels. These floating thresholds can be periodic or determined by the actual residual sound levels as determined by the monitor.

3. ADDITIONAL TECHNIQUES USED IN AIRPORTS

Modern monitoring systems enable users to view noise characteristics and listen to the noise breach to determine the source and take action if it is relevant. However, this approach can create significant false positives each taking up operator time to address and are generally not sufficient to efficiently resolve the problem. Therefore, airport noise management systems have addressed this problem by combining data from other systems. The greatest single enhancement to the noise event technique is to link noise events to actual aircraft movements. This enables systems to link a specific noise measurement, for example, to a specific operation/plane. Although simple in principle, the algorithms required to accurately identify aircraft noise and their sources with high reliability and low error are actually quite complex as they involve time-based correlation to flights plans and/or distance-based correlation to radar, and have to ensure that all flight operations are included.

More advanced techniques have been developed on the basis of noise events. Work has been done to look at the rise and fall times of flight-induced noise events to further reduce data for analysis. These days, the best airport noise management systems go further. They use data from noise models and past measurements to learn, for example, that an A380 has a certain noise level. If the measurement isn't right then it is flagged for attention. This improves the reliability of source allocation and in turn the noise energy associated with aircraft operating at the airport.

4. APPLICATION TO OTHER SOURCES OF NOISE

Urban & industrial monitoring is different. Monitoring at a mine site, for example, includes a wider range of sources with different characteristics and it is not possible to easily separate them from background noise like aircraft. In some cases, particularly large mines, monitoring takes place at the community boundary up to 10km away from the noise sources – where community noise is much louder than the specific noise of interest.

Although some techniques used in airport noise management systems can be and are used, or are adapted to the situation, different techniques are required in urban & industrial noise management. In addition, techniques that allow operators to take action before a compliance breach occurs have been developed.

5. NEW TECHNIQUES FOR INDUSTRIAL NOISE MONITORING

For industrial sources such as those in construction sites, petrochemical plants, waste recycling plants, mines and ports, there are a wide variety of sources of specific sound and, thus, we have to separate them based on other characteristics. Traditionally, noise events, developed for use around airports with necessary data reduction at the noise monitoring terminal, have been used. These are successful in many circumstances but are not always suitable for these applications as the sources have more variable noise signatures. Mine noise from rock crushers, for example, generally starts and continues for hours. Statistical parameters and long-term averaging (avoiding short duration "events") often are useful. Thus, using L_{10} over multiple hours successfully distinguishes it from much shorter duration but higher level community noise.

While airports use radar and flight paths to correlate with noise events and reduce the workload of identifying the sources of noise events, the other applications don't have this input. What many of them do have, however, are electronic Operational Logs and SCADA (supervisory control and data acquisition) (4) systems which provide control and status of remote equipment for display or for recording functions. This provides similar correlation functionality as for airports.

Modern monitoring systems enable users to view noise characteristics and listen to the noise breach to determine the source and take action if it is relevant (5). However, this approach can create significant false positives each taking up operator time to address. In addition, there are a range of practical solutions such as placing noise monitors closer to the sources and extrapolating results to the reference locations (boundary or noise sensitive locations) also helps provided that the difference in levels can be determined and successfully explained to the authorities and surrounding communities.

In addition, directional noise monitors comprising, for example, three outdoor microphones, positioned a precise distance apart in an array, can be used (6). Here, digital signal processes analyse the three signals in real-time to determine the level and directional component to accurately determine where noise is coming from. This enables users to determine if it is due to an industry or process or if it can be attributed to another source. This effectively improves the signal-noise ratio of the noise monitoring terminal by several dB, helping to reduce the number of instances where noise limit breaches require investigation and documentation.

Other, more advanced techniques have also been used but with limited success, often due to cost considerations or due to the method's reliability with the range of sources and sound signatures involved. So, with the current state of the art, in order to provide efficient noise monitoring, it is back to the drawing board.

A noise monitoring and management system must be designed to include all exceedences that can be attributed to specific sound while minimizing those caused by residual sound. This helps to optimize the costs of designing and operating the system. The objective is to reduce investigations of breaches to a manageable level. What you don't want is a situation where you are missing breaches as this makes documentation and communication with authorities and communities much more difficult. The aim is to provide intelligence to better identify sources and to reduce the workload of rejecting levels from irrelevant sources of residual sound.

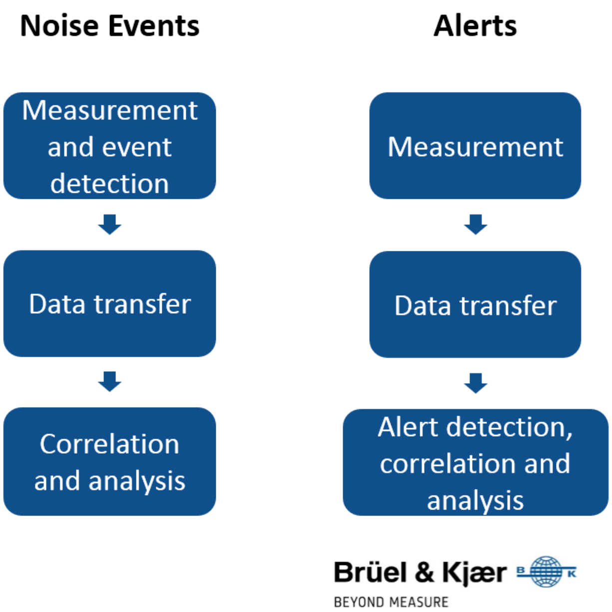


Figure 3 – Comparison of techniques based on noise events and on Alerts

One recently-developed technique which is becoming more widely used is Alerts. This is a 2nd generation Noise Event technique that provides greater flexibility. Here, any input data is processed and combined to give Noise Alerts. Typically, Alerts are directly related to the compliance parameters and limits in the relevant legislation and standards applied to the site. Thus, if the compliance limits are the specific L90 levels over synchronous 20 minute periods, then the Alerts are set up to determine these levels. However, if, for example, noise compliance is in danger of exceedence only when the wind is blowing in a certain direction, then only those cases where the weather monitoring also fulfils these conditions are included. Thus, dogs barking close to the monitor do not always generate Alerts. This can also be catered for by combining Alerts with directional monitoring which can, in addition, help to identify the cause of the compliance breach. Another example is to limit Alerts only to those instances where there are high noise levels at multiple noise monitors. Thus, if one has a noise monitor close to a site, this can be used to indicate noisy activity due to specific sound. Taking into account sound propagation delay, high noise levels at a more remote noise monitor can be filtered to only cause Alerts in instances where the levels at the other, closer proximity location also have been high. Thus, the actual levels at the compliance location are documented.

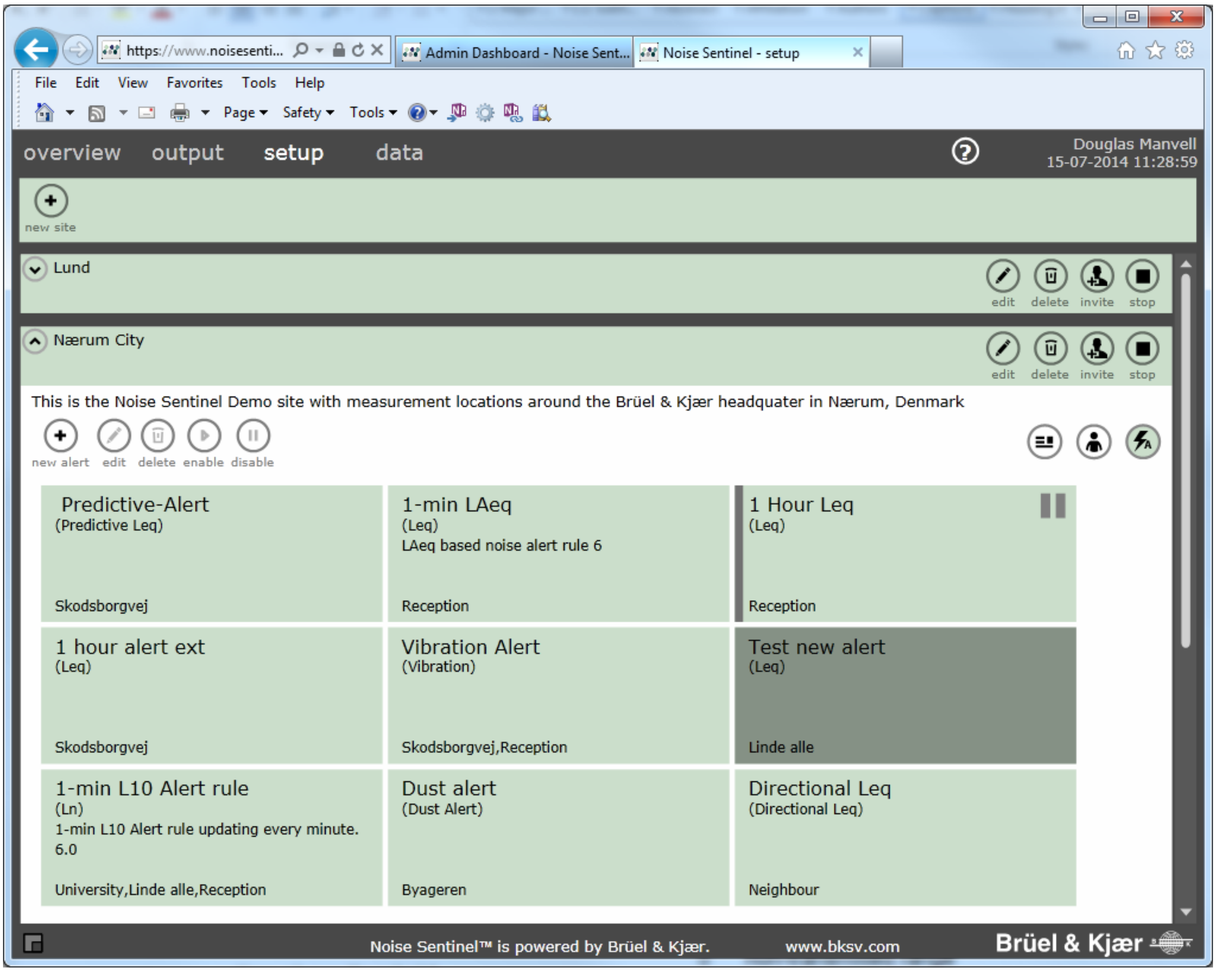


Figure 3 – Examples of Alerts

The technique often utilizes a real-time connection from the noise monitor to a server for better utilisation of the server's processing power and the use of data from separate measurement channels and data sources. In the event of lost connection, a professional implementation of this technique requires that Alerts are calculated on all data, live and historical, to ensure full temporal coverage of the compliance limit monitoring, this giving the authorities and communities confidence in the site owner's reports.

Alerts are typically defined as either Warnings (imminent danger of exceedence) and Alerts (actual exceedences). Often the Warnings are 3-5 dB below the Alerts.

Alerts may also provide Predictive Alerts to warn of potential future compliance breaches. An example of this is if the compliance limit is an hourly L_{A10} level, then the L_{A10} level can be checked at e.g. 5 minute intervals and a Warning issued when the levels over the 5 minute intervals and the current hour are such that continuation of this operational state would cause a breach Alert, enabling the operator to react in a timely manner.

In addition, being done server side enables data measured by the noise management system (noise, weather, etc) to be combined with SCADA data, e.g. using web-services, to provide insight into operational activities and, importantly, enable automated operational management in order to optimize utilization of the environmental noise capacity, thus optimizing output form the site while remaining within the legal noise requirements.

Future work envisioned in Alerts includes the inclusion of noise models and fuzzy logic.

6. SUMMARY – THE BENEFITS OF SYSTEMS WITH ALERTS

Noise events work well where you have lots of discrete disturbances such as individual aircraft departures. They don't work well where you have relatively continuous noise levels such as in an operating mine. Alerts are more fit for purpose because they take account of all of the noise energy rather than first selecting a subset for processing and discarding everything else.

Alerts provide greater flexibility than traditional Noise Events for a wide variety of applications. Alerts provide, of course, immediate alerts when noise levels exceed defined criteria enabling the operator to take immediate action after the breach has occurred. In addition, predictive alerting enables owners to act on potential problems that may occurred in the future, enabling them to maintain compliance. Alerts is a flexible approach that improves determining whether noise limit exceedances are due to specific noise from the operator and minimizes the number of false positives thus reducing the time the operator addresses these. In addition, in combination with SCADA systems enables automated operational management for optimal operational utilization of the environmental noise capacity.

Alerts are an integral part of award-winning noise management systems such as Noise Sentinel (5, 7) for reducing noise pollution and thereby improving the environment. As a result of the above reasons, the Alert concept is beginning to become more widely used.

7. CONCULSIONS

Continuous, unattended noise monitoring systems can immediately alert you should noise levels exceed defined criteria. Once alerted to an exceedance, operators can act to return levels to compliance. The Noise Event technique has been widely used in combination with data from other systems in airport noise management systems for efficient noise management. For industrial applications, another approach is required due to the often complex noise climates. This has led to the rise of the Alert concept.

Using the Alert concept, operators can take proactive action to prevent breaches occurring, thus helping them to maintain compliance. In addition, the Alert concept can better separate specific sound from residual sound, reducing the number of potential noise limit exceedances that need to be investigated and documented (false positives), thus reducing the time operators need to use.

The Alert concept is now successfully in use in a number of waste recycling plants, construction sites, mines and ports and is part of award-winning noise management solutions.

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