Using Post analysis of a noise sample stream in place of noise monitor based thresholds in the detection of aircraft noise

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ABSTRACT

Aircraft noise monitoring systems typically use a fixed threshold on noise monitors for varying times of the day to define what periods of time are to be analysed as possible aircraft noise events. The setting of thresholds leads to significant drawbacks in the continuous measurement of aircraft noise such as:

- Missed aircraft noise due to the threshold being above quieter aircraft levels
- Non aircraft noise being associated as aircraft noise

The experience and capability of personnel that are responsible for the monitoring therefore become paramount in adapting to a continually changing sound environment to ensure reasonable accuracy in reporting aircraft noise.

The objectives of the research undertaken by B&K has been to improve the accuracy of recorded aircraft noise and to minimise reliance on personnel, by replacing threshold based measurements with a recursive searching algorithm based on post analysis of a noise sample continuum.

The outcome of this work has resulted in an aircraft noise event extraction methodology which mitigates the aforementioned drawbacks of existing systems while minimising the dependency on personnel operating aircraft noise monitoring systems.

Keywords: Subsonic aircraft (fixed wing), I-INCE Classification of Subjects Number(s): 13.1.1

1. INTRODUCTION

Continuous unattended monitoring of aircraft noise at and near airports has been undertaken for a considerable lengths of time with the measurement area achieving a level of maturity which is reflected in ISO standards (1, 2).

There are often regional variances on the standards applicable to continuous airport noise monitoring and also variances in the metrics used to report on the recorded noise to government agencies and communities. The variances often come down to vagaries in how communities have perceived the noise and the historical engagement strategies undertaken by successive governments to balance the growth of aviation with the communities living within proximity to the airport.

The commonality across the world has been the use of a noise event: a period in time in which the sound profile exhibits a significant rise above the prevailing residual background. This noise event period is then attributed to being aircraft, non-aircraft or a combination and the required aircraft noise metrics calculated.

A consistent contentious area that is encountered globally in the airport noise monitoring is the trade-off between: recording false positives - non aircraft noise reported as aircraft noise and false negatives - aircraft noise not being attributed to aircraft.

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The impact of false negatives and false positives in the data sets can lead to the stakeholders losing confidence in the measurements and thus the ability to monitor and report on adherence to operational conditions. Therefore techniques that increase accuracy of reported noise metrics are of high value, particularly when they remove or reduce the human involvement.

2. Event Detection versus Event Extraction

The ISO 20906:2009 (2) document lays out the generalized process used in continuous airport monitoring situations; depicted in Figure 1.

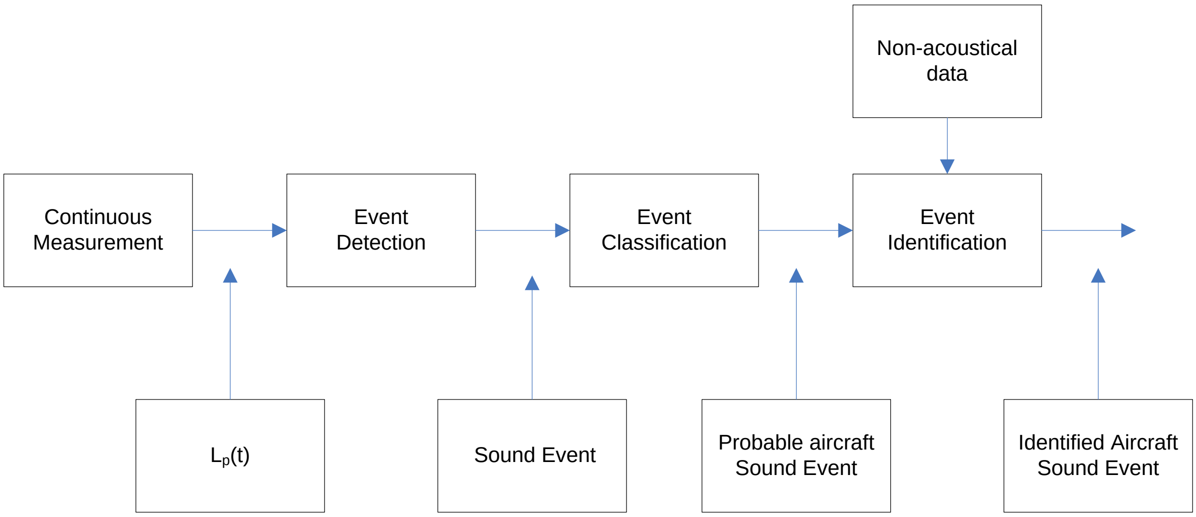

Figure 1 - Continuous Aircraft Monitoring data processing overview

The processing flow highlights the dependency of the event classification and identification processes on what data is fed in, in particular if a noise event is never fed into the event classification process then it is not possible to obtain an aircraft sound event out the end of the process which can then be included in the aircraft noise metrics, resulting in lower than reality aircraft noise metrics.

Historically due to the limited processing capability of noise monitors and the ability of systems to process large volumes of data collected out of continuous monitoring situations the general approach has been to locate monitoring locations in areas with low residual background noise levels to enable fixed thresholds to be set relatively high to avoid extraneous noise being attributed to aircraft. This approach leads to quieter aircraft passes not generating a noise event and for noise events which are created by transient non aircraft noise being recorded, thus leading to false negatives and false positives being sent to the sound event classification and identification processes.

Note that there is the third category of noise event which occurs in continuous unattended monitoring systems where significant levels of non-aircraft noise sources are superimposed on the aircraft noise, this subject area is not covered herein, however significant work and information on this subject area can be found in papers such as those by K. Adams (3, 4, 5, 6).

The target of the research undertaken has been to investigate the feasibility of extracting aircraft noise events at lower levels without the reliance on system operators setting thresholds, additional objectives were to reduce the incident rate of false positives and false negative events prior to the noise event classification and identification process, thereby increasing the system reporting accuracy while lowering the dependencies on the human operators. This has been achieved by making use of the non-acoustical data depicted in Figure 1as part of the process in determining if a noise event should be detected or not refer to Figure 2, this process is done post collection of the acoustic data enabling hindsight to be used in determining what sound events are going to contain aircraft noise.

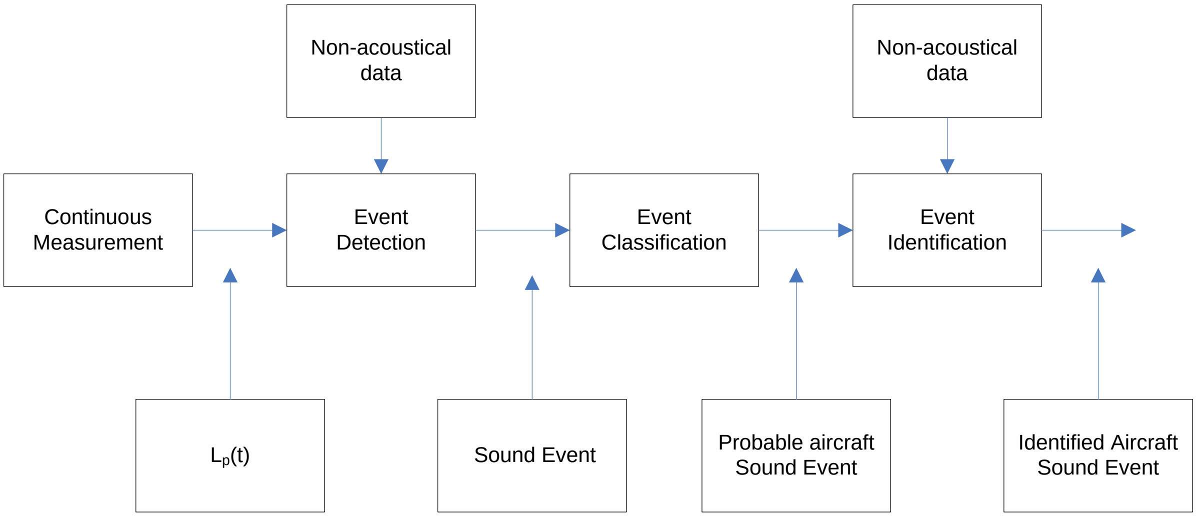

Figure 2 - Use of non-acoustical knowledge into the Event Detection process

The process employed makes use of knowledge obtained from sources outside of the collected acoustic information namely data from RADAR and flight details, these sources enable modelled estimates to be produced of the aircraft operating in the airspace. The estimates provide a guide to what is plausible for the sound profile at each point in time and physical location of interest; this knowledge is then used to search for localized areas of maxima in the sound sample stream at the plausible points in time and a time slice extracted to create a noise event.

Figure 3 depicts a typical sample stream where the fixed threshold for the location has been set at 65dB(A). In the five minute time period displayed in Figure 3 six separate aircraft are clearly audible in sound environment each is associated localized hump in the L_{Aeq} sample trace at 10:14:10:00, 10:14:30, 10:15:40, 10:16:40, 10:18:05 and 10:19:00. The outcome of using predefined thresholds on the sample stream depicted in Figure 3 would be only two noise events get captured: the first in the red shaded area marked with the F and a second in the green shaded area marked with the G and H, and the subsequent aircraft at events at 10:15:40, 10:16:40, 10:18:05 and 10:19:00 would have been missed. Of interest in this sample stream example is the localized rise in at 10:16:10 which looks like a passing aircraft but is in fact from a non-aircraft source.

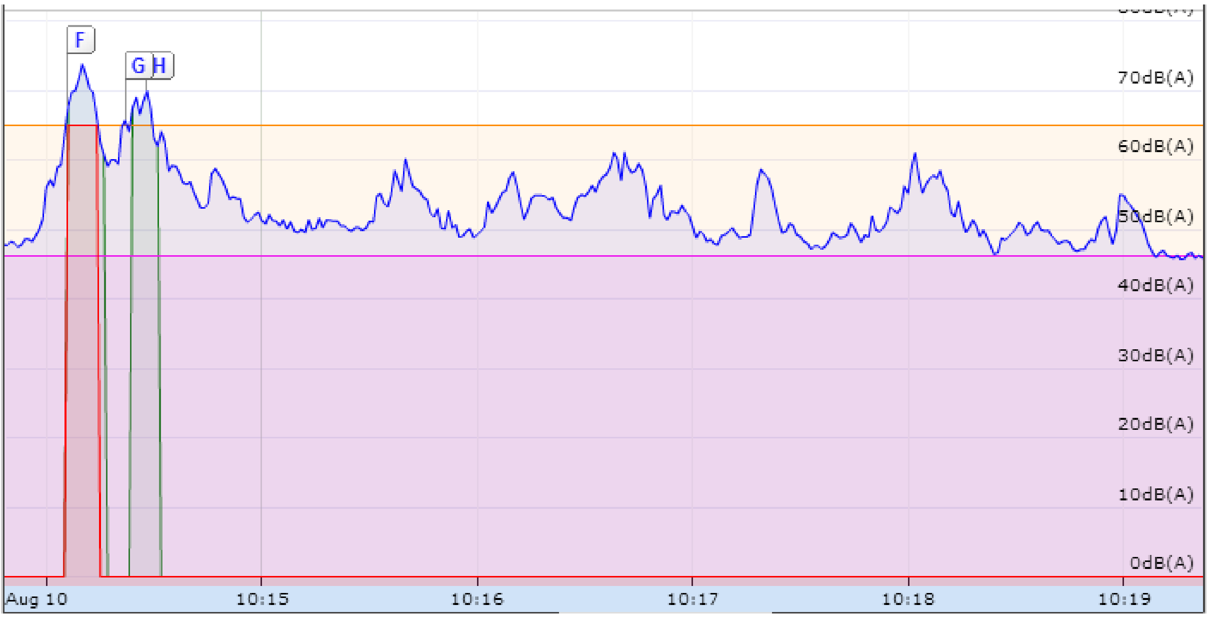

Figure 3 - Typical sample stream of one second L_{Aeq} obtained from continuous monitoring, the nominated fixed threshold for this time of day is depicted by the orange line at 65dB(A).

The common responses to this situation are:

a) Lower the threshold so the other events get picked up into the future
b) Use a floating threshold
c) Do nothing; the quieter events contribution to the typical time weighted aircraft noise metrics is small in comparison with the very loud events.

Lowering the threshold is often not viable as it induces the following typical problems; large increases in noise events being recorded which get classified as aircraft that are not aircraft (increased false positives), noise events that run on from one into the next which then impact the noise event classification and identification process by associating the aircraft noise with the wrong operator, or making the event implausible as aircraft and thus inducing a false negative.

Applying a floating threshold, which moves up and down based on a time constant such as the 90th percentile for the last x seconds, is also problematic as it often leads to the threshold rising and falling either not fast enough or at to slower a pace, thus also inducing the similar set of problems as attempts to lower thresholds.

Do nothing is equivalent to sticking your head in the sand and hoping it will not be found as a concern, this approach is justified in most situations currently as the aircraft metrics required by airports to report on are typically dominated by a few extremely loud noise events, thus the energy contribution form the lower level events becomes irrelevant. This situation is a fortuitous outcome of the industry being born out of an era when 80, 90, 100dB events were a regular occurrence through the early years of jet aircraft. However as the aviation jet industry has matured the occurrence of the extremely loud aircraft has dramatically gone down while the frequency of quieter aircraft noise events continues to rise with the increasing rates of air travel. One thing is for certain communities impacted by hundreds of aircraft events per day start to question why the airport does not measure and report on the noise impact for such movements.

The aforementioned situation arose in a community located near Schiphol Airport outside of Amsterdam. The community performed a study where they collected data on the passing aircraft which they perceived as degrading their sound environment via an attended monitoring process, the outcome of this highlighted that the airports unattended monitoring program was not recording and reporting a lot of the aircraft noise in the area. As a reaction to this B&K undertook a study with Schiphol Airport’s data to apply a new technique; ANEEM (Aircraft Noise Event Extraction Methodology) to compare that outcome with the existing systems threshold based outcome.

3. Gains in Aircraft Noise Detection Rates

The ANEEM was applied to data at two locations the first relatively close to the airport and the second further away, both of which receive regular passes from aircraft during either takeoff or landing. Location 12 is closer to the airport and provides a larger signal to background ratio than location 15 which is further away from the airport in a typical neighboring community setting. Location 12 provides the optimal situation for the existing threshold based noise event collection system, while location 15 is a known problematic location for the existing threshold method of collecting noise event data as the signal to background ratio is much lower and less deterministic by time of day. These 2 locations therefore provided an opportunity to compare the value of the ANEEM against the existing system where conditions are optimal and also well below optimal. The expectation was the ANEEM could outperform the existing system in both situations with the greatest gains to be obtained at location 15.

Data from the week 10-August-2013 to the end of 16-August-2013 was collated and processed, in order to keep data volumes manageable the study only included the influence of flights that passed within 3000meters of the locations and were estimated via a modelling process to create noise levels that would exceed 52dB(A).

Over the week close to 8000 noise events were collated and a truth obtained via listening to audio and/or visual inspection of the third octaves bands in order to make a determination on the noise event containing aircraft noise. The dominance of the aircraft noise in each noise event was not classified as that would have extended the scope into dealing with issues of perception and subjectivity. Hence the truth determination was kept simple to yes/no aircraft noise is contained within the noise event.

Table 1 - Quantity of Noise Events allocated as Aircraft

Methodology	Location 12	Location 15
Thresholds	2532	221
ANEEM	2970	2258

Noise monitors at location 12 and 15 have thresholds of 60dB(A) and 61dB(A) respectively in the existing system, these settings had been defined from many years of data collection and analysis by the system operator. The ANEEM was configured to allow noise events with a maximum one second L_{Aeq} of 52dB(A) to be extracted. It should be noted that the results in Table 1 for the existing systems threshold collected noise events are known to include some false positive events, whereas the results in Table 1 for the ANEEM only contain confirmed aircraft events.

The number of recorded aircraft events increased at both locations thus resulting in the ANEEM successfully outperforming the existing threshold based system. The increase in recorded aircraft noise events is then reflected with increases in the daily aircraft L_{Aeq} metric, as depicted in Table 2.

Table 2 - Gains in daily L_{Aeq} resulting from the increased aircraft event detection rate

	Location 12		Location 15	
Date	Thresholds dB(A)	ANEEM dB(A)	Thresholds dB(A)	ANEEM dB(A)
10-August-2013	54.5	54.9	42.2	48.1
11-August-2013	57.6	57.7	46.2	51.1
12-August-2013	57.4	57.7	45.8	52
13-August-2013	55.0	55.6	38.0	47.2
14-August-2013	53.1	53.6	43.2	49.2
15-August-2013	55.6	55.8	44.5	49.7
16-August-2013	57.5	57.6	47.9	52.2

The increase in L_{Aeq} levels is most significant at the location further from the airport which was missing large numbers of the lower level aircraft noise events, whereas the increase in closer to the airport is smaller due to the existing system picking up the majority of the louder aircraft noise events which then dominate the daily L_{Aeq} metric.

While the daily L_{Aeq} changed very little at one of the locations and significantly at the other this could possibly fortuitous as the existing systems threshold data is known to contain some false positives, thus a view of the distribution of the events was put together as a way of visually identifying how different the set of noise events are between the two methods.

Figure 4 and Figure 5 provide a visual view of the distribution in the recorded events. What is most notable is that at location 15 is that the peak of the distribution has moved down from where it was under the existing threshold scheme. Having the peak of the event distribution lower at location 15 than location 12 is an expected outcome as the aircraft are further away and thus the sound has attenuated further prior to reaching the monitor. The fact that the distribution at location 15 from the threshold based measurement data is at an equivalent noise level to location 12 with closer proximity to the aircraft indicates that location 15 is suffering from a higher ratio of false positive events. This shift in distribution down is supportive of what would be a reasonable expectation when a noise source is further away.

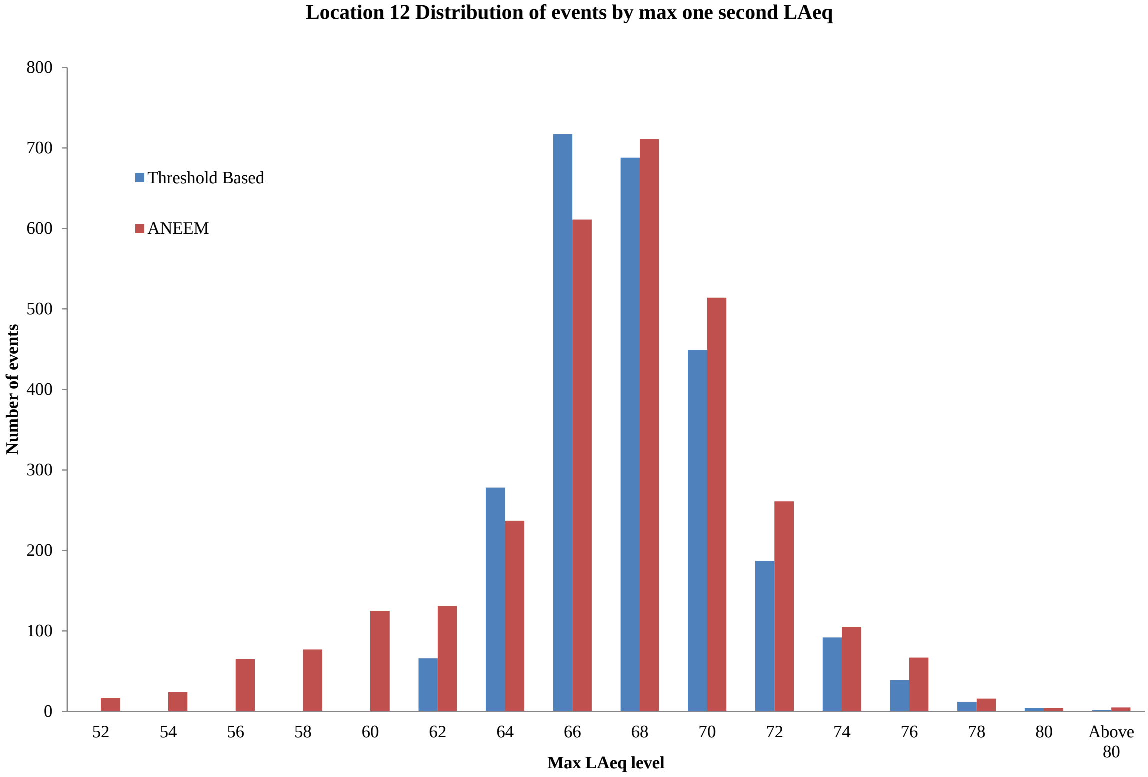

Figure 4 - Distribution of events at location 12

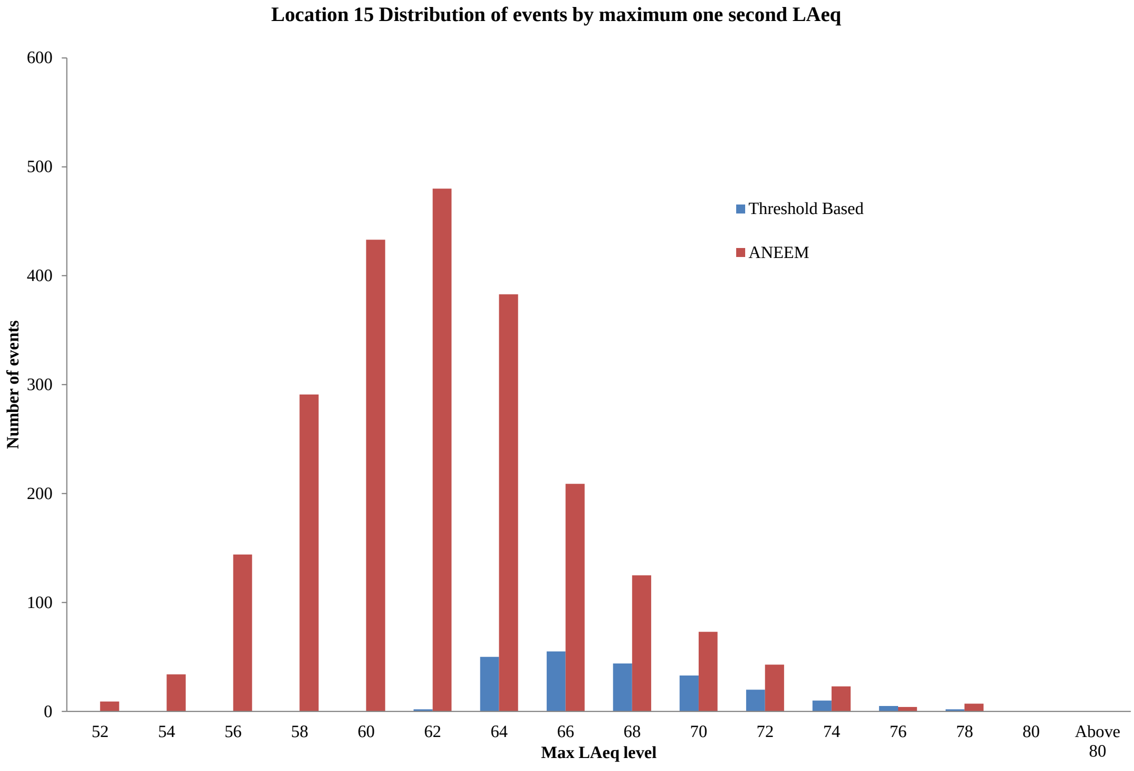

Figure 5 - Distribution of Location 15 events

4. Summary

The ANEEM is able to pick up significantly more aircraft events than existing threshold based systems while improving accuracy rates through the reduction in false positives being classified by event classification processing. This is achieved through a process which is completely automatic and eliminates the dependency on a system operator for tuning parameters to define what thresholds to use and at what time of day. The removal of the human factor is a key benefit in the continuous unattended monitoring scenario as it reduces system performance variability due to operator attentiveness and capability while reducing the ongoing costs of keeping such a system operational and credible in its measurement reporting.

The most notable advantage the ANEEM has over the existing method is in its ability to reliably detect aircraft noise in quieter environments where the levels are below what can be reliably detected by threshold based noise event detection. As has been shown at location 15 this has resulted in a 10 fold increase in the number of detectable disturbances in the sound environment from aircraft.

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