AIRCRAFT NOISE EVENTS – THE CORNERSTONE OF MONITORING

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Abstract

Current procedures for monitoring aircraft noise impact make use of the concept of aircraft noise event. In spite of international agreements to base the impact on LAeq, or LAden, measured over a defined period, significant differences can occur, because of the different ways in which individual noise events are measured. Apart from the differences arising from the algorithmic procedures employed in different jurisdictions, the determination of the event threshold is a key factor in separating aircraft noise from other noise causes. In this paper we compare a number of alternative procedures, including fuzzy thresholds, loudness measures and recognition techniques in order to achieve a more rational noise impact measure. Recent data obtained on site at noise monitoring stations are used to illustrate these procedures. Since the impact measure should correlate closely with community annoyance, aircraft noise abatement services should be looking much more closely at loudness and its refinements, instead of sound pressure, as the basis for monitoring.

Introduction

All automatic aircraft noise-monitoring systems in current use make use of the concept of *aircraft noise event*, hereafter simply referred to as *event*. An event is a period in time during which aircraft noise is perceived to be present, or is dominant, or is particularly annoying. From the data recorded during an event, information is extracted to determine the noise impact and its correlation with particular aircraft types, or airlines or individual aircraft. In view of the importance of this element in the noise-monitoring process, one would expect some standard specification for characterising an event that applies world-wide. But as discussed in [1], there are differences in the algorithms used under different jurisdictions, as well as differences in the way various parameters are chosen within the same jurisdiction. The differences are unimportant if during an event the sound pressure level attributed to aircraft exceeds the sound pressure level in the absence of aircraft by 15 dB. However, difficulties arise when the difference between the attributed aircraft noise and the ambient (background) noise is much smaller, for example less than 5dB.

In the past, much effort has been concentrated on the noise from large jet aircraft at busy international airports. While this area remains vitally important, there is a growing problem at some sites, resulting from light aircraft and helicopters, not so much because of their individual noise impact, but more because of their numbers and the unpredictability of flight paths when numerous aircraft are in the air simultaneously. People living in such areas can complain just as vigorously as those subject to noise from large jet aircraft.

Threshold and its Choice

An event is triggered when a sound level, such as LAeq,1s or LAS_max,1s exceeds a prescribed threshold. The threshold is normally chosen on the basis of experience at each site, with the aim of discriminating against background noise. Some events will be truly aircraft events, others will not be. The aim is to minimize the number of recorded false events and to maximize the number of recorded true events. When radar-tracking information is available, it is usually possible to identify the true events and eliminate the false events.

However, in the case of light aircraft, there is in general no radar information – although from the point of view of flight safety that situation may need to change. In this case, one has recourse only to a judicious choice of threshold, possibly supplemented with recognition techniques based on time-spectral analysis, or directional propagation information (microphone array or intensity methods).

With regard to threshold, the first point to note is that nobody knows exactly how to choose a threshold that is optimal, or sometimes even valid, under common operating conditions. The choice of threshold, whether fixed or dynamically adapting, is inherently uncertain, and therefore the current simple deterministic approach to event monitoring is susceptible to the errors of missed events and false events. Some aspects of the uncertainty have been recognized in the German events detection algorithm [3] and the Swiss detection algorithm devised by the Zürich Airport Authority. The German algorithm ascribes a zero sound exposure level to events for which LAS_max does not exceed the threshold by more than 3 dB. For the Swiss algorithm this limit is 4 dB. In addition, the Swiss algorithm defines a so-called dead zone just before the event commences and just after. The noise in this dead zone does not contribute to the sound exposure level of the event; neither does it contribute to the background noise exposure level. It truly represents an irresolvable uncertainty.

This is precisely the type of situation that fuzzy-set theory [2] was devised to deal with.

Fuzzy Thresholds and Events

In fuzzy-set parlance a conventional threshold is referred to as a 'crisp' threshold. It is a definite pre-determined value. In contrast, a fuzzy threshold is a region within which the decision as to whether the noise level belongs to an event or not is uncertain. For a noise level within this region, there is a rule for assigning a probability, less than unity, that it does belong to an event. For levels outside the region there is certainty (probability one or zero). Levels above the region belong to an event; levels below the region do not belong to the event. To explain how this works, let us consider a concrete example. A crisp threshold T is set at 60 dB. The fuzzy threshold region ranges from 54 to 66 dB, i.e. ± 6 dB around the crisp threshold. We refer to the 6 dB figure as the 'fuzz factor' F. Sound levels above 66 dB are fully assigned to the event; sound levels below 54 dB are fully assigned to the background noise. Levels in the region are assigned to the event according to a simple linear law as follows: the contribution ΔE to the normalised sound exposure of the event is

$$\Delta E_e = \frac{L-(T-F)}{2F} 10^{(0.1*L)} \tag{1}$$

where L is the one-second equivalent A-weighted level of a noise sample. The corresponding contribution to the background noise exposure is

$$\Delta E_b = \frac{T+F-L}{2F} 10^{(0.1*L)} \tag{2}$$

The choice of both the crisp threshold and the fuzz factor is still arbitrary, in that they are based on practical experience. However, the advantage is that the uncertainty of the deciding line between aircraft noise and background noise is reflected in the graded exposure level to be ascribed to these two categories, instead of a full acceptance or full rejection.

A consequence of adopting the fuzzy instead of the crisp threshold is that more events will be recorded and in general they will be of longer duration. This is not a disadvantage if more true aircraft events are found. We applied this approach to four hours of acoustic signal recorded in the neighbourhood of an airport with a predominance of light aircraft and helicopters. The results were

Table 1. Effects of fuzzy threshold with T =60 dB

F (dB)	0	3	4	6
No. of events	30	31	31	31

One of the events was a false event. Use of the fuzzy threshold produced one additional event that was a true event.

These results were obtained by using LAeq,1s as the parameter for testing against the threshold, as is standard in Australia. In Europe it is customary to use LAS_max,1s for this role. When this is applied to the same data set many more false events result. However, these are all of short duration and can be eliminated by suitably increasing the minimum permitted event duration.

An important property of the fuzzy threshold approach is that *the total sound exposure level of all events* is virtually the same as would result from adopting the conventional crisp threshold, *provided the aircraft events are correctly identified* as such in both cases. In contrast to fixed thresholds, fuzzy thresholds give more information about individual events.

Uncertainty and the relevance of loudness

An observer on site at a noise monitoring station near an airport cannot fail to notice that the perceived loudness does not bear a simple relation to the recording of an A-weighted sound level meter. In fact we find that for a combined set of recorded data at the sites around one particular airport, for a sound pressure level of 60 dB, the loudness level varies between 79.6 and 71.1 phon. Conversely, for a loudness level of 73.2 phon, the sound pressure level varies between 52.9 and 62.8 dB. Since aircraft noise is monitored because it is annoying and since loudness and its derivatives give a much better indication of annoyance than A-weighted sound pressure level [5], we should really be basing the monitoring on loudness. Since aircraft noise is usually louder then most background noise at the same sound pressure level, we can begin to see where some of the uncertainty in choosing conventional thresholds comes from. If we now apply loudness level at a crisp threshold of 75.8 phon, all of the previously found true events are found. However, the false event is rejected by the event algorithm, even though its LAS_max value is 68.9 dB. If we now add a fuzz factor of 3 phon to the threshold, one more event is found, which is also a true event.

If the threshold is lowered to 71.1 phon, 23 additional events are found, only two of which are false. Adding a fuzz factor of 3 phon yields one more event, which is also a true event. The minimum value of LAS_max for all these events is 55.0 dB, and it also pertains to a true event. It would not be possible to obtain these results with the conventional threshold and noise parameter technique without inducing several additional false events.

Recognition and loudness threshold

It is beyond the scope of this paper to discuss recognition techniques in detail. Briefly, one type of system employs a neural network to decide at each second whether the noise is predominantly due to aircraft or is background. If the decision is aircraft, a further decision is made to distinguish jets, propeller aircraft and helicopters. Such a system is subject to its own uncertainties and errors, but combined with loudness threshold discrimination a system with significant gains over conventional systems results. Using loudness as threshold discriminator, the true events, with a tolerable number of false events are found. The recognition feature then enables most of these to be found and eliminated from further processing.

Conclusions

We have introduced a number of approaches to improving the basic methods of detecting aircraft noise events. A fundamental uncertainty is recognized which naturally leads to a fuzzy-set approach for its resolution. The fuzzy-set model presented by eq. (1) is the simplest that could be chosen. Several other more sophisticated models come to mind, but the simple model is a good starting point and more experience with its use will doubtless lead to refinements.

Through the issue of uncertainty we are led to loudness as the basic quantity on which we should be basing noise monitoring. This is in addition to the many other grounds for adopting such a viewpoint, which we have not touched on here.

In work of this kind it is essential to work with real data obtained from actual noise monitoring terminals around the airport, where not only the instrumental data are accurately recorded but also the human perception of what is happening in the total soundscape.

Fuzzy thresholds and loudness level are still new techniques in aircraft noise monitoring. Much experience in their use has yet to be gained before they are adopted as mature and standard methods. At the same time, the difficulties of noise management in increasingly complex situations will force changes to conventional ‘standard’ methods.

References

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