MONITORING AIRCRAFT NOISE LEVELS TO THE SIDE OF FLIGHT PATHS

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Assessment of aircraft noise levels near to the main flight paths has been successfully implemented at many airports and a good indication of the aircraft noise levels at those locations is obtained. Monitoring of aircraft noise levels away from the main flight paths is sometimes required to meet community demands and is more challenging as the aircraft noise may not be clearly defined above the background noise level in the area. This paper reviews the recommendations for monitoring aircraft noise in such *'acoustically unfavourable'* locations with particular reference to the findings from analysis of data from such a placement. The outcomes indicate that more sophisticated analysis is required for such placements to achieve a fair and accurate assessment of the aircraft noise levels.

INTRODUCTION

The noise impact from aircraft operations is of concern to those government agencies which have the responsibility for managing environmental noise and to airport operators which have the goal to have maximum utilisation of the airport. In Australia, the basic guidance for planning relating to aircraft noise impact is set out in the Australian Standard "Aircraft noise intrusion – Building siting and construction" [1]. This standard uses the Australian Noise Exposure Forecast system (ANEF) which leads to contour lines on a map around the airport based on the information on the future operations of the airport. The ANEF contour information is used in planning considerations for future developments and to identify those areas which may be subject to mitigation from expansion or changes in the airport operations. As discussed in the paper on "Expanding Ways to Describe and Assess Aircraft Noise" [2], the ANEF system has limitations in community consultation as it does not provide guidance on the actual noise level for different types of operations.

Monitoring aircraft noise around airports is required to obtain information on actual aircraft noise levels. The use of this aircraft noise level data includes identification of those aircraft which do not comply with applicable noise abatement procedures and which may be penalised for such infringements. The data is also used to monitor the actual noise exposure at the location for comparison with estimations, such as that from the ANEF contours, and for future planning.

The basis of any aircraft noise monitoring system is a noise monitoring terminal, which consists of an all-weather microphone located on top of a mast with an attached data logger. The noise level is continuously measured and then transmitted to a central computer for processing. This approach to monitoring was proposed in the 1970s [3] and developed considerably over subsequent decades. The noise monitor will record the data on all the noise in the area so post processing to extract that data that has originated from an aircraft noise event is required. In a basic system this is achieved by rejecting noise events that do not satisfy the acoustic parameters that have been determined to be applicable to an aircraft noise event. The primary parameter is that the noise level of the event must be above a threshold noise level. Then parameters relating to the time profile of the noise event such as the minimum and maximum rise time and fall time of the event are used to extract those most likely to be aircraft noise events.

An improvement in the identification of the aircraft noise events can be achieved with a noise and flight path monitoring system (NFPMS). In such systems, flight path data from the airport on each aircraft movement is used for correlation with the noise event data that has first satisfied the acoustic parameters. The flight path data is usually in the form of radar tracks and altitudes. A 'correlation area' is defined around the noise monitor and checks are made to see if an aircraft was within that area at the time of the potential aircraft noise event. If there were no aircraft movements within the predefined area, the noise event is rejected as not being due to an aircraft. If there was an aircraft movement within the correlation area any noise event that meets the acoustic parameters is considered to be caused by that aircraft.

Most major airports have some form of aircraft noise monitoring installed and there are various commercial systems available. The ANOMS system from Lochard [4] is one such system and is widely implemented around Australian airports. The system is managed by Airservices Australia, which states that the data is used to: [5]

- *determine the contribution of aircraft to overall noise exposure*
- *detect occurrences of excessive noise levels from aircraft operations*
- *assess the effects of operational and administrative procedures for noise control and compliance with these procedures*
- *assist in planning of airspace usage*
- *validate noise forecasts and forecasting techniques*
- *assist relevant authorities in land use planning for developments on areas in the vicinity of an airport*
- *generate reports and provide responses to questions from Government, industry organisations, community groups and individuals.*

Each quarter, reports on the findings from each terminal are made publically available from the Airservices Australia website.

REQUIREMENTS FOR UNATTENDED MONITORING OF AIRCRAFT NOISE

The International Standards Organisation (ISO) released a standard in 2010 on *"Unattended monitoring of aircraft sound in the vicinity of airports"* [6]. This standard aims to specify the "requirements for reliable measurements of aircraft sound" and includes guidance on installations, performance specifications' quantities to be determined, reporting and procedure for determining uncertainty in reported data.

In most cases the monitoring stations are located under or close to the flight paths where the noise from each aircraft movement is well above the general community noise levels, for example positions 1 and 2 in Figure 1. When the system includes flight path data it is not difficult to comply with the requirements of the standard and correctly identify aircraft noise levels for such locations. However for many airports there are increasing complaints about aircraft noise impact from residents at some distance from the main flight paths, for example positions 3 and 4 in Figure 1. To properly assess these concerns the regulatory authority needs quantitative data and so may seek to locate noise monitoring terminals within these residential areas. It is then more difficult to comply with the requirements of the standard and correctly identify aircraft noise levels. Some of the key requirements of the standard which highlight the increased difficulty are discussed in the following sections.

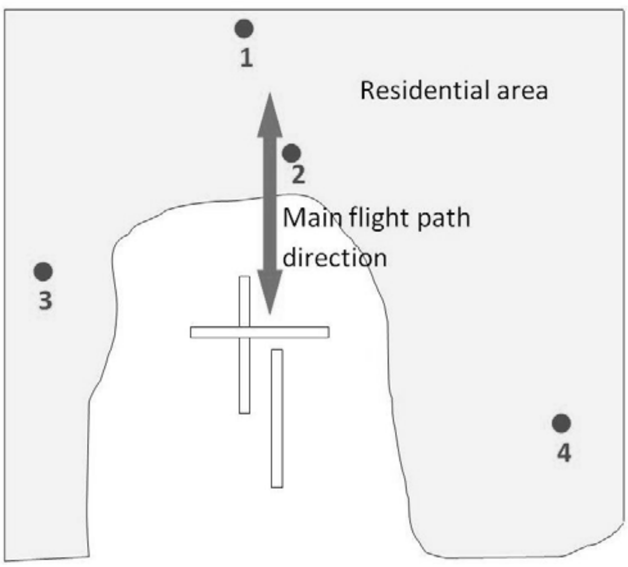

Figure 1. Schematic diagram showing a residential area around an airport with potential locations for noise monitoring terminals. Positions 1 and 2 are close to the flight path and the noise from aircraft would likely be the dominant noise. Positions 3 and 4 are in the residential areas and separating aircraft noise events from general community noise events is more challenging.

Site selection

The standard specifies that a site be selected such that the maximum sound levels from the quietest aircraft to be detected are 15 dB greater than the residual long-time-average sound pressure level. Note that the definition of 'residual sound' is the *'Total sound remaining at a given position in a given situation when the specific sounds under consideration are suppressed'*

The 15 dB guideline allows for the noise to be at least 5 dB above the residual sound before measurement starts and then a clear 10 dB above this value for the determination of the noise event metrics. Figure 2 has been extracted from the standard and shows the critical features in the determination of site suitability. For a slant distance, *s*, assuming spherical spreading, a 10 dB drop will correspond to a flight path distance of 3*s* and an approximate angle, ω, of 70°. For locations close to the flight paths, both s and the portion of the line of sight portion of the flight path within 70° on both sides of the closest point are small. For more distant locations, this portion of the line of sight flight path becomes greater and there is an increased chance that obstacles will be in the way. This will make it more difficult to ensure a 15 dB excess on the residual sound.

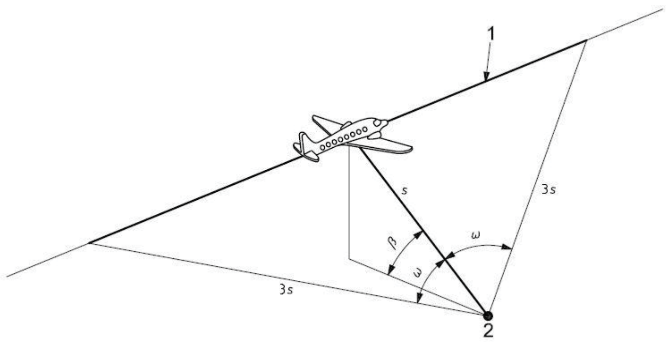

Figure 2. Example for lines of sight to the sound monitor that should be free of obstacles as presented as Figure 3 in ISO 20906 [6]. *s* is the slant distance, *ω* is the line of sight angle, β is the elevation angle relative to the ground plane.

In terms of placement at the location, the microphone needs to be at least 6 metres above the ground and at least 10 metres away from relevant acoustic reflecting surfaces, other than the ground. For microphones mounted on roofs (a common practice with noise monitor terminals in residential areas), it can be difficult to avoid acoustic interference from the roof surface and so a higher uncertainty must be accepted. These factors need to be considered no matter where the monitor is located.

Another recommendation of the standard is that the elevation angle between the ground plane and the sound ray from an aircraft, i.e. angle β in Figure 2, be greater than 30° to reduce ground effects. For distant sideline positions, such as 3 or 4 on Figure 1, it is unlikely that this recommendation will be met.

Sound monitor performance

The sound monitoring part of the system needs to conform to the performance specifications in ISO/IEC 61672 [7] for a class 1 sound level meter. As it is designed to be left unattended in the environment, protection from rain, wind, birds, lightening etc must be provided without affecting the sound level data obtained. These requirements are the same for near and distant locations and are complied with by most aircraft noise monitoring systems.

Measured quantities

A basic requirement is that the sound monitor should be capable of measuring continuous, A-weighted sound pressure levels. The standard provides a listing of the preferred the quantities to be determined to characterise a noise event and these include the sound exposure level, $L_{E,A}$ (to 0.1 dB resolution) and the maximum level, $L_{p,AS,max}$ or $L_{p,A,eq,1s,max}$. A reliable clock is required to enable all sound events to be time-stamped. These requirements are the same for near and distant locations and are complied with by commercial aircraft noise monitoring systems.

Aircraft classification

ISO 20906 [6] states that the main function of a sound monitoring system is to *"reliably and precisely detect and classify aircraft sound events"*. The standard recognises that there are several techniques for correlating measurements from a sound-monitoring system with aircraft movements. The chosen technique should meet the following criteria:

a) *The expanded uncertainty of the measured exposure level for an aircraft sound event shall not exceed 3dB.*
b) *At least 50% of the true aircraft sound events should correctly be classified as aircraft sound events.*
c) *The number of non-aircraft events which are incorrectly classified as aircraft sound events shall be less than 50% of the true number of aircraft sound events.*

At distant locations compliance with these requirements is more challenging as it becomes difficult to separate the aircraft noise events from other noise events in the area using acoustic parameters alone.

The standard does recommend that there be a period of manual identification of aircraft noise levels at the site with at least 20 events of the same type of aircraft being identified with sound level at least 5 dB above background noise levels. Manual identification is time consuming and costly so when a system includes flight path information there is a tendency to rely on the correlation data. Near to the flight path it is probably reasonable to use the flight path data in lieu of manual identification as a check of the initial set up. However at distant locations the risk of incorrectly attributing a noise level from a local event to an aircraft is considerably greater than for a location close to the flight paths and checking using flight path data alone may not be adequate. Correct identification of aircraft noise events and accurate noise level data for those events are the critical factors for obtaining useful information from a NFPMS so it is essential that this checking be done at the initial set up of the system.

The standard recommends that the primary identification of a noise event being due to an aircraft should be based on acoustical data including knowledge of the typical length of an aircraft sound event for the site, relationship between the maximum sound pressure level and the sound exposure level, spectral information, correlation with events at other sites, listening to the sound event recorded and acceptance that wind speed is not excessive. If non-acoustical data, e.g. flight path data, is available, the standard recommends that the sound data may be further checked to ascertain if the event could be identified with a particular aircraft operation.

As the standard recommends a primary determination of aircraft events be based on acoustical information, the setting of the acoustical parameters for an aircraft noise event is essential. An idealised aircraft noise event time profile shown is shown in Figure 3 [extracted from 6]. At more distant locations from the flight path the aircraft noise event will differ from this idealised profile. Thus identification primarily on acoustic parameters becomes more difficult and therefore there is a tendency in such set ups to rely even more heavily on the flight path data. As discussed in the following sections, this approach can still lead to incorrect attributions of aircraft noise levels.

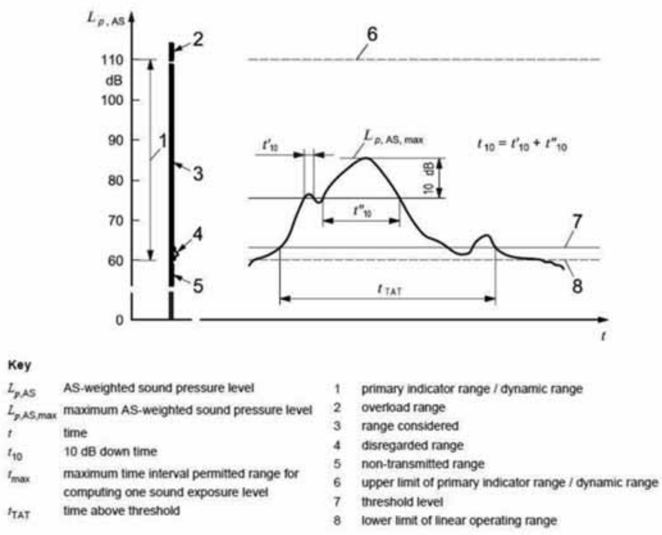

Figure 3. Example of aircraft noise event criteria, Figure 5 in ISO 20906 [6]

CASE STUDY OF NOISE MONITORING AT SOME DISTANCE FROM THE FLIGHT PATHS

Background on installation

The airport under consideration has approximately 910 Regular Public Transport (RPT) aircraft flights per week (47,320 per year) and approximately 70 General Aviation (GA) aircraft flights per week (3,640 per year). There has been an ongoing concern about aircraft noise from RPT aircraft operations and from GA aircraft overflights from the residents approximately 3 km to the side of the flight path to the north of the airport, as indicated in Figure 4.

Such concern about aircraft noise would not be anticipated due to the location and the noise abatement measures in place for the aircraft operations. The airport has a noise abatement zone that requires most RPT aircraft to be higher than 5,000ft above ground level before overflying residential areas. This means that departing and arriving RPT aircraft do not overfly the residential area which is approx 3.8 km from the end of the runway. Outside the ANEF 20 contour around the airport is considered acceptable for residential areas in accordance with Table 2.1 in AS 2021 [1]. The residential area under investigation is approx 2 km outside that contour and also 1.2 km to the side of the 65 dB contour for the noise footprint predictions for a Boeing 737-800 aircraft. Preferred tracks for

GA aircraft attempt to minimise overflights of the residential areas. Those that do overfly the area can be as low as 300m. To investigate the ongoing concerns a portable monitor as part of a NFPMS was installed at the edge of the residential area to obtain data on the aircraft noise levels in the area.

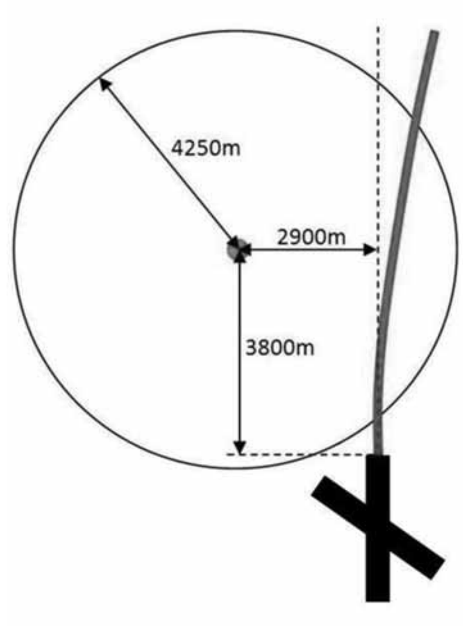

Figure 4. Schematic layout of the monitoring location in the residential area and the typical flight path used by RPT aircraft.

Compliance with the installation requirements

As the site was far to the side of the main flight path where the RPT aircraft were climbing, the elevation angles were well below the 30° minimum required in ISO 20906 [6] and so there was greater risk of ground effects affecting the data. For RPT aircraft operations the slant distance, *s*, was large and so there was an increased chance of obstacles within the angle ω affecting the data. However for the GA aircraft flying near the site the requirements for elevation angle would be met and the slant distance, *s*, was small.

From long term monitoring at the site, the $L_{Aeq,24hr}$ was found to be 49 dB(A) and the $L_{Aeq,night}$ was 42 dB(A). The expected aircraft noise levels for most RPT and GA aircraft operations were not likely to be more than 15dB above the residual noise. .

Thus, in the terms of the ISO Standard, this site is *"acoustically unfavourable"*. However, in view of the ongoing complaints, it is the relevant location for aircraft noise monitoring to try to quantify the aircraft noise levels. It is particularly important under such circumstances for the post processing of the data to not only to optimise the acoustic parameters used to classify an aircraft noise event but also to use as much non acoustic data as possible to minimise incorrect attributions of noise levels to aircraft.

NFPMS installation and Data Reporting

The basic acoustic parameters in the system and settings used at this installation are summarised in Table 1. Those responsible for the installation made the decision to set very broad parameters to avoid missing potential aircraft noise events with the belief that the flight path data correlation would enable rejection of non-aircraft noise events.

Table 1. Acoustic parameters used to identify potential aircraft noise events at the case study installation

Threshold, i.e. the trigger noise level above which the noise data is considered potentially due to an aircraft.	55.0 dB(A)
Minimum rise time before, and minimum fall time after the maximum level for the noise event level	0 dB/sec
Maximum rise time before, and maximum fall time after the maximum level for the noise event level	5 dB/sec
Pre-trigger and post-trigger time which allows for analysis of the data for some time before and after the maximum level has been identified.	5 sec

The need to rely greatly on the flight path data meant that the location of the correlation area was critical. For installations close to the flight path, a circle with radius 1 to 2 km and centred on the noise monitoring will allow for reasonably reliable identification of noise events that satisfy the acoustic criteria and which could be attributed to aircraft operations. For the case study location to the side of the main runway it was necessary to use a single correlation circle with radius 4.2 km to capture the closest approach of the aircraft following prescribed flight paths. This meant that a noise event at the monitor would be tagged as generated by an aircraft if it was operating anywhere within the large correlation area.

Accuracy of Aircraft Noise Data

The main data from the NFPMS is used for the production of reports on aircraft noise levels. The database does include a large amount of additional information on each noise event that is not normally used in the standard reporting process. Detailed analysis by the authors of all the data obtained over a 72 day period allowed for a better understanding of the extent of incorrect attributions of aircraft noise levels.

If there are intense storms to the north of the airport, RPT aircraft are instructed not to follow the usual flight paths as a safety precaution. During the analysis period there were a few RPT aircraft which flew almost directly over the noise monitoring terminal. Figure 5(a) shows the noise level versus time profile for one such event which was correctly identified and classified by the NFPMS and is more than 20 dB above the background noise levels. Figure 5(b) shows the profile for a similar aircraft type following the standard departure track. The maximum noise level during the event is just 10 dB above the background. The noise level profile and the time of the noise event are somewhat comparable and it is reasonable to accept that the noise event in Figure 5(b) is correctly attributed to an aircraft. In contrast Figures 6(a) and (b) show the profiles of two noise events which were also attributed to RPT aircraft that were somewhere in the correlation area. These profiles clearly differ greatly from the profiles in Figures 5(a) and (b); one is extremely short duration and the other has an atypical profile. The standard reporting process would identify these as aircraft noise events but this is unlikely to be a correct attribution.

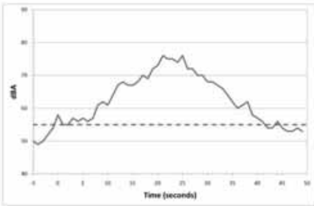

Figure 5(a). Noise profile for a jet aircraft flying directly overhead the NMT,

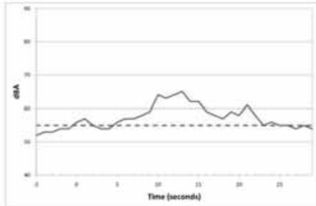

Figure 5(b). Noise profile for a jet aircraft following a standard departure track, putting it approximately 3 km from the monitor

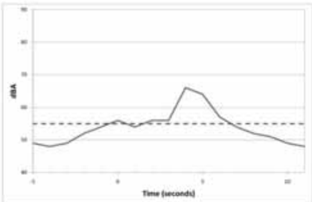

Figure 6(a). Noise profile attributed to a jet aircraft but with very short time duration.

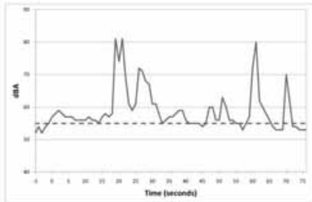

Figure 6(b). Atypical noise profile attributed to a jet aircraft.

GA aircraft could fly near to the noise monitoring terminal and so there was a better chance of accurate attribution of noise level. Figure 7(a) shows the noise profile which is likely to be a correctly attributed event for a helicopter and 7(b) for a small fixed wing aircraft. Figure 8(a) shows a profile attributed to a GA aircraft with an atypical noise profile and which would seem to be from rain noise. The maximum noise level for the event in Figure 8(b) is just above the threshold but the time period is too short for this to be a valid aircraft noise event and is more likely due to a local noise.

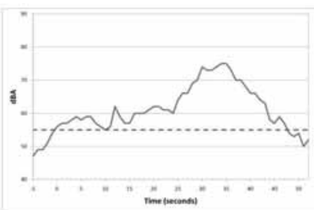

Figure 7(a). Noise profile attributed to a helicopter directly overhead the noise monitoring terminal.

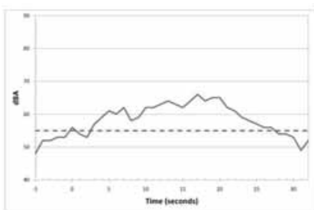

Figure 7(b). Noise profile attributed to a small fixed wing aircraft directly overhead the noise monitoring terminal.

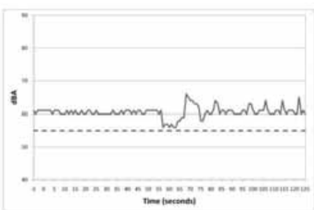

Figure 8(a). Atypical noise profile attributed to a GA aircraft.

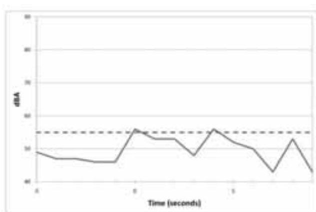

Figure 8(b). Noise profile attributed to a GA aircraft but with a very short time duration and atypical profile.

As the GA aircraft travel at a lower speed they could be within the correlation area for some time and local noise events occurring during that time period could lead to multiple incorrect attributions of aircraft noise levels. From the detailed analysis of 2713 events the data over a 72 day period, multiple noise events occurring within 1 minute were attributed to the one aircraft on 641 occasions. While GA aircraft can make multiple passes over a location these could not occur within such a short time period.

After removing these incorrectly attributed multiple events, 2071 correlated noise events remained and of these only 383 (18.5%) had a maximum noise level at least 10 dB above the threshold of 55 dB(A). As it was impractical to look at every noise event in detail, samples of noise events focussing on those less than 10 dB above the threshold were studied in detail. This analysis used the additional data that is captured but not normally used in the usual reporting process. Included in this analysis was viewing the flight path used by the aircraft to see if it was in the direction of the noise monitor, comparing the time the aircraft passed through specified points for correlation with the higher noise levels in the profiles, comparing the time duration of the noise event with a valid aircraft noise event etc. This detailed analysis confirmed that there was a high rate of incorrect attributions of noise events to aircraft from the NFPMS and this affected the assessment of the aircraft noise levels in the area.

DISCUSSION

Techniques to improve the correct attribution of aircraft noise levels are essential to obtain useful data at *"acoustically unfavourable"* sites. Both Wallis [8] and Adams [9] have emphasised that correct identification of aircraft noise events are critical. The NFPMS captures more data than is used in the normal reporting process. Some of the techniques used in the detailed examination in the case study were time consuming as they were done manually but there is scope for these to be automated. For example, the removal of duplicate noise events attributed to the same aircraft and the removal of events with time duration less than or greater than a prescribed time period. More sophisticated methods need to be employed to remove those profiles that do not comply with the typical noise profile and to provide a better discrimination of aircraft noise events [e.g. 10]. Even with the application of more sophisticated methods for correct identification of aircraft noise levels there may still be incorrect attributions.

The use of a correlation circle for identification of an aircraft in the region has limitations when the monitoring location is to the side of the flight paths and so the area of the circle becomes very large. Alternative shapes for the correlation area could assist to reduce incorrect attributions particularly at busy times for the airport operations when there are a number of aircraft in the vicinity of the airport. Correctly identifying the location of the aircraft at the time of the maximum noise level could assist with correct discrimination of aircraft noise events and such systems are available [e.g. 11].

Audio files for each potential aircraft noise event could be used to identify dubious events remaining in the data base.

While this may be time consuming it would further assist with correctly identifying aircraft noise events for *“acoustically unfavourable”* sites.

CONCLUSIONS

Assessment of aircraft noise levels near to the main flight paths has been successfully implemented at many airports. The development and refinement of aircraft monitoring systems have led to improvements in the analysis and reporting systems so that a good indication of the aircraft noise levels at those locations is obtained. Monitoring of aircraft noise levels away from the main flight paths is more challenging as the aircraft noise may not be clearly defined above the background noise level in the area. However there is a need to obtain data on aircraft noise levels in these *‘acoustically unfavourable’* locations.

Following ongoing complaints from residents, a noise monitoring terminal was located in the residential area to the side of the main flight paths for RPT aircraft but subject to overflights by GA aircraft. The detailed analysis of this data has highlighted the difficulties in obtaining accurate attribution of aircraft noise events from the NFPMS. More sophisticated analysis and the use of audio files are required to achieve a fair and accurate assessment of the aircraft noise levels for such *‘acoustically unfavourable’* locations.

ACKNOWLEDGEMENT

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