AIRPORT NOISE
Prediction of aircraft noise emitted during ground operations

Maria Rabiega, Rafal Tarczynski, Andrzej Jaroch

Wroclaw University of Technology, ul.Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland 
e-mail: MarAn@zakus.ita.pwr.wroc.pl

This paper aims at presenting the calculating model for predicting long term equivalent sound level near the airfields, generated during noisy aircraft ground operations. In the vicinity of airports noise is affected not only by landing and taking off of aircrafts but also by noisy aircraft ground operations. An airplane is represented by a single point source described by immission relevant sound power level, directivity characteristic, speed of moving along taxiway and time of run-up operation. Input data was collected for a passenger aircraft at the Wroclaw airport under normal working conditions. The computer program facilitating calculations was developed. The program draws the contours of equal $L_{A_{eq}}$.

INTRODUCTION

The resultant sound level nearby airports is affected also by certain ground operations which are related to taxiing of an aircraft from stand or sleeve to the beginning of the runway, and after landing, from the runway to the stand. Also, noise generated by auxiliary power units (APU) or other external generators used to maintain air-conditioning systems and power electrical equipment during the plane’s stop over between subsequent flights has influenced the equivalent level. Noise levels emitted by those operations are very harmful to the ground crews.

MATHEMATICAL MODEL

The output parameter of the model is an equivalent sound level in dB(A) which is calculated from a superposition of noise emitted by plane during all activities on the ground. Known mathematical models used to calculate noise generated by aircraft are based on profiles of equal noise levels. In the model described here, similarly as in the analysis of noise propagation by other mobile sources such as trains or cars [1,2,3], plane noise is substituted by a single point source characterized by immission relevant sound power level and directivity pattern. The value of sound power level is changing in time and is affected mainly by the type of operations performed by the craft. Noise emitted during run up procedures was calculated as for point source also noise of external is represented as a single point source positioned at the spot corresponding to the center of the plane at stand. In the model described here, airplane’s pass-by is represented as a series of point source spaced every 1 meter along the taxi way and $L_{A_{eq}}$ is calculated from (1).

$$L_{A_{eq}} = 10 \log \left( \frac{1}{T} \sum_{i=1}^{M} \left( 10^{L_{w} - K(\alpha)} \right) \frac{t}{2\pi r_{i}^{2}} \right) \tag{1}$$

where:
- $M$ - total distance of the taxiing way, [m];
- $L_{w}$ - immission relevant sound power level of plane for taxiing operation, determined at $\alpha = 90^\circ$, [dB];
- $r_{i}$ - distance between $i$-th point source and the observer, [m];
- $K(\alpha)$ - directivity index, [dB].
- $t = 1/v$, $v$ - speed of airplane during taxiing [m/s].

EXPERIMENTAL DATA

Parameters of the model described above were determined on the basis of measurements and observations carried out at the airport during its normal working
conditions. It was possible to record and measure noise of single airplane’s activity because Wroclaw is not a very busy airport. There weren’t any obstacles between the plane and the point of measurement. The following turbo propelled planes were tested: ATR42, ATR72, DASH and FOKKER50. Directivity pattern was determined on the basis of the short-time equivalent level measurements around airplane, at 8 points, spaced regularly every 45° along the perimeter of 25 or 30 m radius circle. Fig. 1 illustrates the results obtained for noise measurements for ATR42 airplane. As can be easily seen, with one engine running, directivity propagation is clearly asymmetric with prevailing noise levels on the side of the running engine. On the other side of the plane ($\alpha = 270^\circ$) the noise level is lower due to the screening effect of the cockpit and the fuselage. After engaging the propeller an increase of noise level along directions $\alpha = 0^\circ$ and $180^\circ$ can be noticed. After engaging the other propeller the characteristic becomes symmetric.

<table>
<thead>
<tr>
<th>type of plane</th>
<th>$L_w$ taxiing [dBA]</th>
<th>$L_w$ stand [dBA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATR 42</td>
<td>123.5</td>
<td>128</td>
</tr>
<tr>
<td>ATR 72</td>
<td>127.5</td>
<td>128</td>
</tr>
<tr>
<td>DASH</td>
<td>116.5</td>
<td>124</td>
</tr>
<tr>
<td>FOKKER 50</td>
<td>123.5</td>
<td>131</td>
</tr>
<tr>
<td>AN 26</td>
<td>134.5</td>
<td>-</td>
</tr>
</tbody>
</table>

The maximum speed of taxiing is between 25 $\div$ 30 km/h. Time of engines and propellers start up is the pilot’s decision. Normally, it takes 1 $\div$ 1.5 minute. It is also the pilot’s decision whether to taxi with one or two propellers running. After landing, it is normal for the crafts to taxi using only one propeller. External generator is treated as an omnidirectional point source of acoustic power level equal to approx. 104 dB.

**REFERENCES**

2. Transportation Noise - Reference Book - Butterworth 1987,
5. *INM Integrated Noise Model 5.1* FAA AEE-120 – computer software used to predict noise impact in the vicinity of airports.
The simulation of airport noise impact can be employed to acoustically characterize the areas around the airports, and to define the territory town-planning peculiarities; the simulation also allows to measure sound levels on the ground and the acoustical impact due to the departure tracks.

This study is focused on the effects produced by ground orography and changes in flight parameters on noise impact, considering only departure procedures, looking for the less disturbing exit procedures. The study is organized in three phases:

- On site acoustic measurement of a significant number of flights;
- Model calibration;
- A typical airport day simulation, with different calculation settings, realized over 9 stations sited on the diagonal of the square containing the studied territory.

### ON SITE MEASUREMENTS

On-site measurements were taken in a typical airport working day, considering only departures. Once the SIDs were known the measurement stationing was sited near Taino playing field.

Taino is a little town sited on the vertical of the tracks which interest the territory, and it is a good observation point for the aircrafts; its ambient noise is about 37 dBA.

![Figure 1](image1.png)

**Figure 1.** Scheme of the tracks considered in the study. They are all and only departures. The symbol ⛰ represents the position of Taino.

### CALIBRATION

Basing on acoustical measurements and on direct aircrafts observation, flight parameters were defined in the model, which are considered to be the real ones.

![Figure 2](image2.png)

**Figure 2.** Comparison between standard departure profiles and noise-abatement departure profiles (NADP).
TYPICAL DAY SIMULATION

A typical day traffic was simulated using the official data of the airport. Each depart were associated exit tracks basing on the foreseen destination and on the aircraft model. The results are displayed for 9 points (Tab. 1) at different altitudes, and also by isophonic maps. The simulation was realized with four different calculation settings:

- Departures with program’s default settings on “flat” territory and with the orography;
- Departures, with the parameters optimized during the calibration phase, on flat territory and with the orography.

OBSERVATIONS AND CONCLUSIONS

The point-to-point results (Tab. 2) show that differences of some dBA can be observed dependently from the orography, and of 5 dBA combining the effects of the orography with the aircrafts’ flight profiles setting.

To point out the less noisy runways it is necessary to take in account real aircrafts procedures and territorial peculiarities.

REFERENCES


ACKNOWLEDGEMENTS

We want to thank

- Mr. Jeff Olmstead, ATAC Corporation;
- Mr. Joe DiPardo and Mr. Jhon Gulding, FAA;
- Mr. Gregg Fleming, Volpe National Transportation System Center;

for their kindness in helping to reach the aim of this work.

<table>
<thead>
<tr>
<th>Measured Leq (dBA)</th>
<th>Extended Leq -16 hrs (dBA)</th>
<th>Simulated Leq Real data (dBA)</th>
<th>Simulated Leq Standard data (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.90</td>
<td>41.89</td>
<td>40.2</td>
<td>37.1</td>
</tr>
</tbody>
</table>

Table 1. Comparison between measured and simulated noise levels – calibration phase

<table>
<thead>
<tr>
<th>Point Nr.</th>
<th>Standard Profiles</th>
<th>Real Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without Terrain</td>
<td>With Terrain</td>
</tr>
<tr>
<td>1</td>
<td>46.2</td>
<td>46.2</td>
</tr>
<tr>
<td>2</td>
<td>48.6</td>
<td>48.8</td>
</tr>
<tr>
<td>3</td>
<td>50.3</td>
<td>50.9</td>
</tr>
<tr>
<td>4</td>
<td>50.0</td>
<td>50.6</td>
</tr>
<tr>
<td>5</td>
<td>47.4</td>
<td>47.6</td>
</tr>
<tr>
<td>6</td>
<td>44.0</td>
<td>44.1</td>
</tr>
<tr>
<td>7</td>
<td>41.2</td>
<td>41.2</td>
</tr>
<tr>
<td>8</td>
<td>39.8</td>
<td>39.9</td>
</tr>
<tr>
<td>9</td>
<td>39.7</td>
<td>39.7</td>
</tr>
</tbody>
</table>

Table 2. Comparison between measured and simulated noise levels – study phase
Noise Mapping around the Malpensa International Airport

S. Curcuruto\textsuperscript{b}, A. De Leo\textsuperscript{a} and C. Fabozzi\textsuperscript{a}

\textsuperscript{a} National Agency for the Environmental Protection of Italy, Via V. Brancati, 48 – 00144 ROMA (Italy)
\textsuperscript{b} Regional Agency for the Environmental Protection of Lazio, Via Garibaldi, 114 – 02100 RIETI (Italy)

The consequences on the management of the Malpensa International Airport is the economic increase of the territorial area of Lombardia and Piemonte for occupational and business reasons but is evident also a environmental impact in the same area. Noise is the most important pressure factor for the population living in the vicinity of Malpensa. Aim of this extraordinary noise measurement campaign coordinated by ANPA is evaluate the realistic acoustic impact of this infrastructure in the territory.

Italian law references

In order to reduce the noise pollution around civil airports the Italian legislator in the specific regulation has defined many prescriptions to carry out in every civil airport.

The prescriptions provide that it will define the airport acoustic area, the part of territory influenced by airport activities comprised in the 65 dBA isolevel noise curve, and inside of it, it be required to locate the three respect zones in which are imposed particular noise limit. Besides for every airport it must to be established the anti-noise flight procedures in order to:

- minimize airport acoustic area;
- minimize the percentage of population exposed to high noise level;
- assure that the area delimited from the 75 dBA isolevel noise curve is inside the flight operation zone.

These fulfilments need, first of all, to calculate the aircraft noise in the vicinity of the airports, in particular for Italian regulation it be required to determine the evaluate aircraft noise level ($L_{eq}$).

To define this acoustic descriptor is possible to use two ways:

1. carrying out noise measurements in-situ;
2. carrying out previsional simulations using a specific noise evaluation model.

Monitoring acoustic campaign

The article presents the study activity arranged and defined in a technical team coordinated by ANPA, in which were present ARPA of Piemonte and of Lombardia, Varese Province, SEA (Management Society of Milano Airports).

The extraordinary noise measurement campaign around Malpensa airport for 90 days from 20/4/00 had the aim to verify the noise values reported in the minimum impact scenery (fig.1).

This scenery was defined with a noise evaluate model using the anti-noise flight procedures in force in the airport at the beginning of the noise measurement campaign. In this representation have been characterized the contours of the isolevel noise curve of 55, 60, 65, 75 dBA of $L_{eq}$, and also the three zone A, B and C as defined in the specific national regulation.

The study activity has provided for the comparison the $L_{eq}$ values determined in-situ in the specific measurement positions with the simulated values represented with the isolevel noise curves above-mentioned.

The measurement positions, where were placed the 24 noise monitoring station, were chose along the tracks followed by the aircraft during the departure or approach operation, particularly they were picked near the isolevel noise curves defined in the minimum impact scenery.

The noise monitoring stations installed for this campaign have measured continuously the sound pressure level using an outdoor microphone put at least 3m from the ground.

The acoustic measurement set-up provided for:

1. Recording of one second Short Leq;
2. Recording of daily Leq Time history or sound event time history;
3. Individualization of sound events connectible with aircraft flights using a fixed noise threshold and a minimum time that it is exceeded. The threshold and the minimum
time period are defined in relation of the acoustic site characteristic;

4. Determination for the sound events of this information:
   - date and event start time;
   - event time period;
   - SEL, $L_{eq}$, $L_{A_{max}}$

The Varese Province with the own technical office CED (Data Elaboration Institute) has elaborated all the acoustic data received by the acoustic stations and also has executed, in order to recognize the sound event of aeronautic nature, the matching with the radar tracks of aircraft during the departure or approach operation.

The whole acoustic data recorded in the three months in the 24 measurement station elaborated and controlled by ANPA were delivered to the Environmental Minister that had requested this study.

Synthetically it possible to affirm that the $L_{eq}$ values measured in the campaign, for the most part of measurement stations, correspond apart from ±2 dBA to the $L_{eq}$ values, reported as isolevel curve in the minimum impact scenery.

We have to say that the acoustic data measured in-situ aren’t directly comparable to the values indicated in the minimum impact scenery, in fact during the 90 days of the measurements period the flight paths (the anti-noise flight procedure) in form in the Malpensa airport had some changes, and also they often didn’t follow by the pilots. Besides the average air traffic during this campaign has been lower of that considered in the modellistic simulation of the minimum impact scenery.

**Definition of real modellistic sceneries**

During the study activity it was decided to execute the calculation of real scenery with the INM model using not the theoretical paths assigned to the aircraft, indicated in the Notam in force in airport, and the generic number of aircraft in departure and approach from the two runways of Malpensa, but using the real radar tracks of the aircrafts and the real air traffic recorded in the three months period.

In particular it was decided to choose some days of the campaign considered more significant for which to calculate the real scenery using the methodology above-mentioned. Moreover it was decided to compare the values $L_{eq}$ measured in-situ with the isolevel noise curve of the real scenery for the significant days and with the numeric $L_{eq}$ simulated in the same way for all days of the acoustic campaign.

I regard that this proceeding operative can assurance un good comparison between values measured and values simulated with the evaluate model in fact we use for obtain the both values the same input information.

The results of these final elaboration have nearly finished and they could give a more exact evaluation of the realistic acoustic impact of this infrastructure in the territory.

**Measurements campaign results**

**ACKNOWLEDGMENTS**

I thank the colleagues of ARPA Piemonte dip. Novara, ARPA Lombardia dip. Varese, dip. Milano dip. Milano Parabiago, Varese Province, SEA that worked in the monitoring campaign and in the subsequent data elaboration.
Validation of previsional noise model INM at Pisa “G. Galilei” International Airport

G. Licitra, A. Farnetani

ARP A T, Dipartimento di Livorno, Via Marradi 114, 57126 Livorno, Italy

Italian laws permit to use a previsional noise model to define the respect area around the airports, to fix the noise abatement procedure and to locate noise monitoring terminals that check them. The precision of the model depends on the approximations assumed in calculation algorithm in regard to atmospheric conditions, land modelling, noise fluctuations of single aircraft, but also on reliability of the input data. In order to use the Integrated Noise Model of the F.A.A. as a valid tool for European airports and fleets, measurements have been carried out around the Pisa International Airport and compared with model results. The model seems to be most accurate near flight paths (±2 dB(A)), and gets worse when the distance increases (±4 dB(A)), above all because of inaccuracy in calculating lateral propagation that it has been analyzed by means of specific measurements. A better algorithm will be implemented in a new version of INM. The model is however a useful tool to predict the impact of future growth of the airport and to plane it.

INTRODUCTION

Pisa airport is a military airport used by civil aircrafts too. It is located in the southern part of the city, near to the sea. There are two parallel runways, 37 degrees sloped respect to magnetic North. Only one of the runways is used for landing and takeoff, while the other is used for taxing. The main runway is used in both direction for flight operations. It depends by meteorological conditions: normally the preferential direction is south, because it does not involve flying over the city but if the tail wind component exceeds 10 kts or for safety reasons due to performance of aircraft, takeoff and landing are performed in the North direction. A considerable acoustical annoyance for inhabitants of areas near the airport is produced in this case. Most of all, the takeoff procedure in north direction involves to turn left and flight over all the city because of hills in North-East direction. By means of a statistical study of the wind intensity and direction and effective use of runway it has been estimated that the mean annual percentage of takeoff and landing in north direction is 15%. During the noise monitoring study we had carried out, the flight percentage over the city reached 50% in one day while the mean value was 10% in the entire period. The FAA’s Integrated Noise Model (INM) was used for estimate the real acoustical situation of areas near to the airport and for predict the future settings of the same areas due to airport growth until 2010. The development of the airport, and also the use of secondary runway for approach and departure, will produce an increase of passengers of 57% in the next 10 years. The Italian regulations about airport noise define three areas around the airports delimited by noise contours of italian index for airport noise evaluation (\( L_{VA} \)): A zone (\( 60 < L_{VA} < 65 \)); B zone (\( 65 < L_{VA} < 75 \)); C zone (\( L_{VA} > 75 \)). There are precise limitations for some activities in these areas. This study aims at define the location points to install the terminals of noise monitoring system issued by italian regulations. This monitoring system will allow to control the respect of the procedures adopted to reduce the aircraft noise in the areas close to airports. It is worth while remember that italian regulations do not take into account the military aircrafts and so they are not included in this study. In the case of Pisa airport, military flights are a great percentage (also 50%) of the entire air traffic and the direction of this flights is not regulated.

INSTRUMENTS AND METHODS

For the validation of INM, a monitoring noise study was carried out for six months to take into account the variations of meteorological parameters that can influence the sound propagation. Four noise monitoring stations was placed to validate the model. The location of the stations was chosen as follows: one on the southern side of airport along the centerline of the runway at a distance of 500 m from the runway end, the other three on the northern side of airport, in urban area, along the ground track at distances between 10 m to 400 m from this. The monitoring terminal also included a DAT recorder to verify noise levels. The terminals were located far from buildings or on high positions (roof), so the differences between ambient noise and aircraft noise was greater than 20 dB. The time history was derived by measured data and SEL for each identified event was calculated. Military aircrafts and unrelated events were checked by a time correlation between recorded event and flight data got from Pisa Airport. A specific aircraft and flight operation was associated with every measured SEL and a database was made to verify the uniformity of measured levels.
Table 1. Mean of differences between levels at the end of the runway and those ones at lateral position, compared with INM outputs in the same locations for different aircraft type.

<table>
<thead>
<tr>
<th></th>
<th>Departure data n.</th>
<th>Measured (dB)</th>
<th>INM (dB)</th>
<th>Approach data n.</th>
<th>Measured (dB)</th>
<th>INM (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2J wing</td>
<td>57</td>
<td>2.6 ± 1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>67</td>
<td>9.9 ± 1.2</td>
</tr>
<tr>
<td>2J tail</td>
<td>86</td>
<td>2.4 ± 1.3</td>
<td>1.8</td>
<td>1.8</td>
<td>94</td>
<td>9.8 ± 2.3</td>
</tr>
<tr>
<td>3J tail</td>
<td>4</td>
<td>2.7 ± 1.4</td>
<td>1.3</td>
<td>1.3</td>
<td>4</td>
<td>7.8 ± 1.0</td>
</tr>
<tr>
<td>2T</td>
<td>150</td>
<td>2.3 ± 1.7</td>
<td>1.8</td>
<td>1.8</td>
<td>185</td>
<td>8.8 ± 1.7</td>
</tr>
</tbody>
</table>

RESULTS

The 28 days with most flights in north direction was selected for the validation, for each day data from two monitoring terminals are available. Considering $L_{DNj}$ for each day, $L_{DN}$ is calculated as follow:

$$L_{DN} = 10 \log \left( \frac{1}{N} \sum_{j=1}^{N} 10^{L_{DNj}/10} \right)$$  \hspace{1cm} (1)

where $N = 7$ days for each location point. In Fig. 1 are displayed the $L_{DNj}$ calculated with INM and the measured ones. The plotted line is $y = ax$, where $a = 0.99 \pm 0.01$ and it is obtained by best linear fit. The coefficient $a < 1$ shows that the INM lightly overestimates the true values. The linear correlation coefficient is $r = 0.92$ and it proves a good agreement with the searched linear relation. The mean deviation $\sigma$ between calculated ($x_i$) and measured ($y_i$) levels can be used for estimate the INM accuracy. In Tab. 2 the value of $\sigma$ for some data groups is showed. For a mean traffic day the model error is less than about 2 dB(A). The INM accuracy improves increasing the number of flight (see Coltano), and if the monitoring station is nearest to ground track (see Pisanova and S. Ermete), while the gap between measured and calculated data increases with the distance from the ground track (see Piagge). Other measurements were carried out to evaluate the lateral attenuation of aircraft noise given by INM. One terminal was located at the end of the runway and the other laterally, 200 m far from the first, both inside the airport. The correlation between events and aircraft type was made as in the previous case and then the data were divided into four groups according to engine type and installation ($J =$ jet, $T =$ turboprop). Tab. 1 shows the mean of differences between levels at the end of the runway and those ones at lateral position, compared with INM outputs in the same locations. The approach values are greater than the departing values because of the relative position of aircraft and measurement’s locations. The takeoff data are not easy to compare without radar track’s data or video recording systems, because the altitude of each aircraft varies in accordance with aircraft model and takeoff mass. However during the approach all aircrafts flight along the 3 degrees sloped descend path. One can find that the INM overestimates the lateral attenuation (above 4 dB) during landing: better prevision is necessary and it could be given by the new version of INM [1] that is in progress.

### Table 2. Value of $\sigma$ for different locations with the number of flights indicated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Terminal</th>
<th>$\sigma$ dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{DN,j}$</td>
<td>Coltano (1429)</td>
<td>1.9</td>
</tr>
<tr>
<td>$L_{DN,j}$</td>
<td>S. Ermete (44)</td>
<td>3.1</td>
</tr>
<tr>
<td>$L_{DN,j}$</td>
<td>Pisanova (70)</td>
<td>3</td>
</tr>
<tr>
<td>$L_{DN,j}$</td>
<td>Piagge (128)</td>
<td>4.1</td>
</tr>
<tr>
<td>$L_{DN,j}$</td>
<td>all (1671)</td>
<td>2.9</td>
</tr>
<tr>
<td>$L_{DN}$</td>
<td>all (1671)</td>
<td>1.7</td>
</tr>
</tbody>
</table>

REFERENCES

Low noise emission rolling and take-off procedures: monitoring of courier carriers for the Orio al Serio airport

A.C. Bertetti$^a$, R. Martelli$^b$ and M. Masoero$^c$

$^a$Studio Progetto Ambiente s.r.l., Corso Rosselli 44, 10128 Torino, Italy
$^b$S.A.C. B.O. S.p.A., Aeroporto di Orio al Serio, Via Aeroporto 13, 24050 Orio al Serio (BG), Italy
$^c$Dipartimento di Energetica Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

The verification of the acoustic impact determined by the introduction of alternative take-off procedures, with respect to the ones presently adopted, with reference to the city of Orio al Serio (Bergamo, Italy) and to the municipalities along the Eastward exit routes that are most exposed to noise, falls in the frame of studies aimed at the planning of night flights and at the optimisation of the “noise budget” of the airport. The results allow a comparison of the acoustic performance of alternative take-off procedures, and of the noise reducing strategies applicable to the Orio al Serio airport. Furthermore, the adoption of a “slot allocation” policy, i.e. the priority assignment to flights of silent carriers aimed at optimising the loading capacity of the environment (available annual noise load), can be based on the experimental results.

INTRODUCTION

The bill of law 72280 art. 28, presently under examination by the Environment Commission of the Italian House of Parliament, re-proposing the contents of D.P.R. (Decree of the President of the Republic) 9 November 1999 n. 476 [1], suspended by the TAR (Regional Administrative Tribunal) of Lazio, introduces the banning or the limitation of night flights, a fact that induces very severe operative constraints for national airports specialised in courier and all-cargo traffic. SACBO, the company that manages the Orio al Serio (situated near Bergamo, about 50 km east of Milano) airport, has therefore decided to evaluate the effects determined by the adoption of alternative take-off procedures, aimed at reducing the night-time noise annoyance for the residential areas near the airport. The experimental activities have been co-ordinated with DHL, in order to achieve a more effective involvement of the pilots in the tests, and to obtain a higher level of information about the carriers. The experimental data in the municipalities situated Eastward of the airfield (Cassinone, Bagnatica) have been provided by the monitoring network of the Province of Bergamo.

POSITION OF THE MICROPHONES

The positioning of the microphones reflects the goals of the acoustic inquiry, which is aimed at acquiring information on the noise impact on the southern urban area of the Orio al Serio and, at the same time, at verifying the consequences on the territory situated east of the Serio river. The map of Figure 1 shows the position of the five microphones:

- RM-AE-H5/7: 2 microphones 189 m from the runway axis, height +5 m and + 7 m with respect of the present noise abating hill;
- RM-08: 1 microphone at the first floor of residential building “Casa 1”;
- RM-11: 1 microphone at the second floor of residential building “Casa 3”;
- RM-12: 1 microphone at the first floor of residential building “Casa 2”.

Measurements have been performed simultaneously in all points: A-weighted SPL (fast) were recorded every 0.5 seconds; the clocks of the data acquisition units were previously synchronised.
TAKE-OFF PROCEDURES AND TYPE OF CARRIERS CONSIDERED

All night take-offs presently take place from RWY11, from west towards east. Three types of take-off procedures have been examined:

- **TEST1**, take-off from a stand still, at position Alpha (east of RWY11), applying the appropriate take-off thrust;
- **TEST2**, rolling take off from the beginning of the runway: gradual thrust is applied to reach the appropriate take off thrust at position Alpha;
- **TEST3**, take off from a stand still at the full length position (RWY11), applying the appropriate take off thrust.

The carriers utilised by DHL include 1 B757, 2 A300 and 4 B727. Totally 14 TEST3, 5 TEST2 and 8 TEST1 take-offs have been examined, partially including some flights by operators other than DHL.

RESULTS

The results of the monitoring activities (A-weighted SEL values for selected take-offs are given in Table 1) provide valuable results, both in terms of performance comparison of different take-off procedures, and in terms of noise reduction strategies applicable to the Orio al Serio territory.

a) Independently from the take-off procedure and type of carrier, the maximum impact occurs at receptor RM-08, which is closest to the beginning of the runway, and the minimum impact at receptor RM-12, situated on the second row of buildings. Rolling take-offs and take-offs from Alpha always penalise, at different degrees depending on carrier type, the eastward territory.

b) For the B727 the procedure determining the maximum impact in all positions is that with gradual acceleration (TEST2), while the best results are given by TEST1 with take-off from Alpha for receptor RM-11, and TEST3 (traditional procedure) for receptor RM-12.

c) For the A300 the procedure determining the maximum impact is the rolling take-off (TEST2), while the best performer is the take-off from Alpha (TEST 1) for all receptors.

d) For the B757 no significant differences occur at point RM-08, located in front of RWY11, with a slight impact increase for the traditional take-off. Similarly to the B727, the best results are given by TEST1 for westerly point RM-11 and by TEST2 for easterly point RM-12. The difference between running and traditional take-off at points RM-11 and RM-12 is negligible.

In order to improve the situation in the most critical residential area of Orio al Serio, presently characterised by Lva > 75 dB(A) (zone C), the following short- and medium-term strategies may be adopted:

**Short-term scenario (until April 1st, 2002):** before phasing-out of Chapter 2 carriers, maintain for the B727 the take-off from RWY11. For the A300 and B757, albeit their contribution to Lvan is marginal in presence of the B727, a take-off from position Alpha is preferable.

**Mid-term scenario (after April 1st, 2002):** after phasing-out of the B727, the adoption of take-off from position Alpha, furthermore reducing the impact on the south-west residential area of Orio al Serio, is advisable.

REFERENCES


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Table 1. Summary of the results (SEL [dB(A)])

<table>
<thead>
<tr>
<th>RECEPTOR POINT</th>
<th>CARRIER TYPE</th>
<th>TEST 1 (Alpha)</th>
<th>TEST 2 (Rolling take-off)</th>
<th>TEST 3 (RWY11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM-08</td>
<td>B727</td>
<td>108.0</td>
<td>109.3</td>
<td>105.4</td>
</tr>
<tr>
<td></td>
<td>A300</td>
<td>100.8</td>
<td>104.5</td>
<td>101.1</td>
</tr>
<tr>
<td></td>
<td>B757</td>
<td>95.2</td>
<td>95.0</td>
<td>96.1</td>
</tr>
<tr>
<td>RM-12</td>
<td>B727</td>
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<td>99.1</td>
<td>95.3</td>
</tr>
<tr>
<td></td>
<td>A300</td>
<td>89.0</td>
<td>90.3</td>
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<tr>
<td></td>
<td>B757</td>
<td>87.1</td>
<td>84.3</td>
<td>85.3</td>
</tr>
<tr>
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<td>102.9</td>
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<tr>
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<td>A300</td>
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<td>94.4</td>
</tr>
<tr>
<td></td>
<td>B757</td>
<td>85.5</td>
<td>89.5</td>
<td>90.0</td>
</tr>
</tbody>
</table>
Acoustic Analysis of the Aircraft Noise around a Regional Airport

G. Cesini, A. Iannotti, E. Mattei

Dipartimento di Energetica, Università di Ancona, via Brecce Bianche, 60100 Ancona, Italy

The study concerns the description of a methodology for the evaluation of the acoustic impact of the airport activities in the surrounding areas of the airport of Ancona-Falconara, a regional airport situated in central Italy. The acoustic impact in the surrounding environment of the airport has been analysed through a series of measurement campaigns with automatic stations. As it is not possible to have radar plots of the aircraft operations for the identification of the aircraft which is involved in the airport area, both data supplied by the airport authorities and acoustic spectra sent out by aeroplanes have been considered. The recording of the spectrum sent out during flying over is an element to recognize an aeroplane and allows to combine the relevant source to a determined, recorded sound event. Eventually, the experimental results have been compared with some data obtained by previsional numeric model in order to check its reliability and evaluate the effectiveness of possible noise abatement actions afterwards.

INTRODUCTON

The study of the acoustic impact at the airport “Raffaello Sanzio” of Ancona-Falconara (Italy), a regional airport situated in central Italy near the Adriatic Sea, has been carried out in order to evaluate the acoustic influence of the airport activities in the surrounding areas. The beginning phase of the study concerned the set-up of previsional methodologies in order to evaluate noises produced by aircraft activities developed in the airport for each single event and for the totality of sound events. The previsional model used for the evaluation of the noise produced by the aircraft activities is the Integrated Noise Model (INM) carried out by the Federal Aviation Administration of the United States of America. Afterwards, phonometric recording has been carried out both with movable and fixed measurement stations in different points around the airport; such measurements have both had the purpose of checking the results given by the predictive model and the task of analysing the acoustic influence of every single air movement in order to define possible noise abating procedures afterwards. Several conditions on either air traffic or flights and different distribution among different directions of landing and take-off have been supposed.

EVALUATION OF THE ACOUSTIC IMPACT AND SPECTRA’S ANALYSIS

The comparison between the data obtained by INM model and the data measured shows that the evaluation level of the airport noise deduced by the calculation underestimates the measured Lva level of 2.3 dB(A). This value can be considered to be representative of the inaccuracy of the model with regard to the real situation referred to the airport considered. The evaluation index LVA is defined by the Decree of the Italian Ministry of Environment on October, 31st 1997. LVA corresponds at DNL level.

The identification of the event has also been confirmed using some information on the air traffic by the airport of Falconara supplied by the ENAV (air traffic controllers). However, it is important to say that this information presently concerns only the kind of aircraft, the type of event (take off, landing, flying over, touch and go) and the runway used, while radar plots are not available. In order to improve the identification of the aircraft which are involved in the airport area, the analysis of acoustic spectra sent out by aeroplanes during take-off and landing near the airport has been considered. The recording of the spectrum sent out during flying over at the moment of take-off and landing is an important element to recognize an aeroplane and allows to combine the relevant source to a determined sound event recorded with automatic stations. It is not always easy to identify a determined sound event recorded near an airport for a certainty, even using data supplied by the airport authorities or by radar plots. The recording of the spectrum supplies a further element in this identification and facilitates the task of characterization of the airport areas with the relevant classification.

The analysis of acoustic spectra has been considered for these aircraft, which are the most used in the airport of Ancona-Falconara: Boeing 737-400, MD 80, ATR 72 and Antonov 12. The first two aircraft are with jet engines, while the second two are with turbo-prop engines. Moreover the acoustic spectra of helicopters has been considered. At first, the maximum level
spectra and the spectra of the event equivalent level have been considered. The analysis shows that the standard deviation is lower when the sound spectrum of the event equivalent level with values of 2-3 dB on average is considered. In particular, the standard deviation has been lower for landing operations whose situation is quite predictable considering the fact that landing, differently from taking off, occur in an instrument way and so with lower possibilities of changing flight tracks. The graphs of the results divided between landings and take-offs are shown in the pictures no. 1 and 2.

![Picture No. 1: Acoustic analysis of spectra during takeoffs](image1)

![Picture No. 2: Acoustic analysis of spectra during landings](image2)

**CONCLUSIONS**
The comparison of these data allowed to check the possibility of recognizing aircraft using the study of acoustic spectra. In first analysis, this study allows the possibility of distinguishing jet aircraft from turboprop aircraft. Indeed, the spectra show the presence of tone components in the spectra of turboprop aircraft. The possibility of recognizing jet aircraft is much more complicated; actually, the spectra of the MB 80 and B 737 are similar to each other during taking off, while it is possible to identify the two different types of aircraft during landing. At the end, the spectra of helicopters are well defined because of the strong presence of components in low frequency. The study, which is presently in a beginning phase, requires the analysis of a bigger number of events in order to make the standard deviation more controlled depending on a check about different measurement stations as well.

**REFERENCES**