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# Evaluation of aircrafts noise propagation in the Palanga airport

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## Introduction

Among the problems related to the protection of the population against urban noise an important place belongs to the issues on aircraft noise. Increase in the power of aircraft engines and the growing flow of air transportations caused a significant noise increase in the vicinities of the airport. The situation has become complicated that as a result of the growth of our cities, distances between the cities and air ports get reduced. At present, airports in Vilnius and Palanga are found within the city territories or close to their boundaries. Therefore city buildings have already surrounded the territories of airports from two-three sides. A similar situation exists as regards the airports in the major cities of other countries in the world. It should be noted that aircraft noise is distinguished by high sound levels and a large area of pollution within the territory. Thus the increased interest in aircraft noise, organizational and technical measures, aimed at achieving the reduction of unfavourable effect of noise on the population, may be explained.

An unfavourable effect of noise on man is usually related to general irritation, noise disturbances when speaking and listening to the radio, watching TV; inability to get sleep or early awakening, difficulty to concentrate on the performance of a specific work, and under the long-term effect of noise the possible health exacerbation, etc. A degree of that effect depends on the human reaction to noise and on the physical specifications of noise. For evaluation of the effect of noise, it is necessary to investigate it. Since the Palanga Airport is situated close the largest and most important health resort of Lithuania, aircraft noise, as well as its effect on the holiday-makers, was measured and evaluated.

Noise measurements of aeroplanes, landing and taking-off in the Palanga Airport, were conducted in August 2000.

## Methods for noise measurement and calculation reference noise measurement points

An aeroplane, during measurements conducted in accordance with these International Standards [1], shall not exceed the noise levels specified t the following points:

1. *A the lateral reference noise measurement point:*

1.1. For subsonic jet aeroplanes: at the point on a line parallel to and 450 m from the runway centre line, where the noise level is a maximum during take-off;

1.2. For propeller driven aeroplanes: at the point on the extended centre line of the runaway vertically below 650 m from the flight path, where the climb is at the full take-off power rating.

*The noise measurement point below the flight path with the full take-off power rating is an alternative lateral noise measurement point for propeller driven aeroplanes.*

2. *Flyover reference noise measurement point:* the point on the extended centre line of the runway and at a distance of 6.5 km from the start of roll;

3. *Approach reference noise measurement point:* the point on the ground, on the extended centre line of the runway 2 000 m from the threshold. On level ground this corresponds to a position 120 m (395 ft) vertically below the 3° descent path originating from a point 300 m beyond the threshold.

The maximum noise levels, when determined in accordance with the noise evaluation method, are given in the following sections of methods for noise measurement and calculation.

## Calculation of effective perceived noise level from measured noise data

The calculation procedure which utilizes physical measurements of noise to derive the EPNL evaluation measure of subjective response shall consist of the following five steps:

1. The 24 one-third octave bands of sound pressure level are converted to perceived noisiness by the methods given in the Table. The no values are combined and then converted to instantaneous perceived noise levels, PNL($k$);

2. A tone correction factor, $C(k)$ is calculated for each spectrum to account for the subjective response to the presence of spectral irregularities;

3. The tone correction factor $C(k)$ is added to the perceived noise level to obtain tone corrected perceived noise levels, PNLT($k$), at each one-half second increment of time

$$PNLT(k) = PNL(k) + C(k).$$

The instantaneous values of tone corrected perceived noise level are derived and the maximum value, PNLTM, is determined

4. A duration correction factor, $D$, is computed by integration under the curve of tone corrected perceived noise level versus time;

5. Effective perceived noise level, EPNL, is determined by the algebraic sum of the maximum tone corrected perceived noise level and the duration correction factor

$$EPNL = PNLTM + D.$$

## Perceived noise level

Instantaneous perceived noise levels, PNL($k$), shall be calculated from instantaneous one-third octave band sound pressure levels, SPL($i$, $k$) as follows.

*Step 1.* While converting each one-third octave band SPL($i$, $k$), from 50 to 10 000 Hz, to perceived noisiness $n(i,k)$, by reference to the special Table of Perceived Noisiness.

*Step 2.* The perceived noisiness values, *n(i,k)*, found in step 1 by the following formula, are combined:

$$N(k) = n(k) + 0{,}15\left\{\left[\sum_{i=1}^{24} n(i,k)\right] - n(k)\right\} =$$

$$0{,}85 n(k) + 0{,}15 \sum_{i=1}^{24} n(i,k),$$

where $n(k)$ is the largest of the 24 values of $n(i,k)$ and $N(k)$ is the total perceived noisiness.

*Step 3.* The total perceived noisiness, $N(k)$ is converted into perceived noise level, PNL(*k*), by the following formula:

$$PNL(k) = 40{,}0 + \frac{10}{\log 2} \log N(k).$$

## Correction for spectral irregularities

Noise having pronounced spectral irregularities (for example, the maximum discrete frequency components or tones) shall be adjusted by the correction factor *C(k)* calculated as follows:

*Step 1.* Calculations start with the corrected sound pressure level in the 80 Hz one-third octave band by calculating the changes in sound pressure level (or "slopes") in the remainder of the one-third octave bands as follows:

$s(3,k) =$ no value,

$$s(4,k) = SPL(4,k) - SPL(3,k),$$

•

•

$$s(i,k) = SPL(i,k) - SPL(i-1,k),$$

•

•

$$s(24,k) = SPL(24,k) - SPL(23,k).$$

*Step 2.* Those values of the slope, $s(i,k)$, are encircled, where the absolute value of the change in slope is greater than five; that is, where:

$$|\Delta s(i,k)| = |s(i,k) - s(i-1,k)| > 5.$$

Step 3.

3.1. If the encircled value of the slope *s(i, k)*, is positive and algebraically greater than the slope *s(i*-1,*k)*, then SPL *(i, k)* is encircled;

3.2. If the encircled value of the slope *s(i, k)* is zero or negative and the slope *s(i*-1*, k)* is positive, then SPL*(i*-1*, k)* is encircled;

3.3. For all other cases, no sound pressure level value is to be encircled.

*Step 4.* New adjusted sound pressure levels SPL' *(i, k)* are computed, as follows:

4.1. For non-encircled sound pressure levels, let the new sound pressure levels equal the original sound pressure levels, SPL' *(i, k)* = SPL *(i, k)/*

4.2. For encircled sound pressure levels in bands 1 to 23 inclusive, let the new sound pressure level equal the arithmetic average of the preceding and following sound pressure levels:

$$SPL'(i,k) = 1/2\left[SPL(i-1,k) + SPL(i+1,k)\right].$$

4.3. If the sound pressure level in the highest frequency band (*i* = 24) is encircled, let the new sound pressure level in that band equal:

$$SPL'(24,k) = SPL(23,k) + s(23,k).$$

*Step 5.* New slope $s'(i,k)$, including one for an imaginary 25-th band, are recomputed as follows:

$$s'(3,k) = s'(4,k),$$

$$s'(4,k) = SPL'(4,k) - SPL'(3,k),$$

•

•

$$s'(i,k) = SPL'(i,k) - SPL'(i-1,k),$$

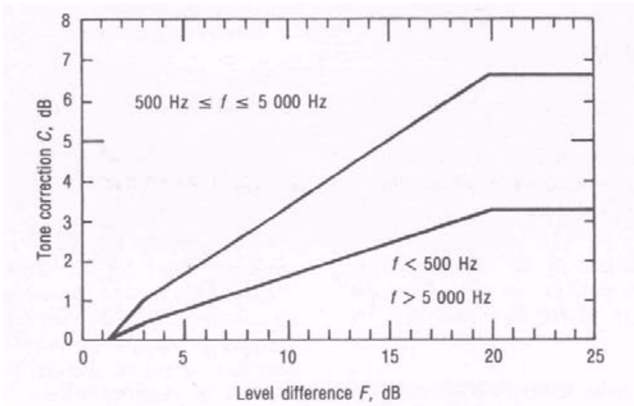
•

•

$$s'(24,k) = SPL'(24,k) - SPL'(23,k),$$

$$s'(25,k) = s'(24,k).$$

Table 1. **Tone correction factors**




| Frequency $f$, Hz | Level difference $F$, dB | Tone correction $C$, dB |
|---|---|---|
| $50 \le f < 500$ | $1\frac{1}{2}^{*} \le F < 3$ | $F/3 - \frac{1}{2}$ |
| | $3 \le F < 20$ | $F/6$ |
| | $20 \le F$ | $3\frac{1}{3}$ |
| $500 \le f \le 5\,000$ | $1\frac{1}{2}^{*} \le F < 3$ | $2F/3 - 1$ |
| | $3 \le F < 20$ | $F/3$ |
| | $20 \le F$ | $6\frac{2}{3}$ |
| $5\,000 < f \le 10\,000$ | $1\frac{1}{2}^{*} \le F < 3$ | $F/3 - \frac{1}{2}$ |
| | $3 \le F < 20$ | $F/6$ |
| | $20 \le F$ | $3\frac{1}{3}$ |

* See Step 8, 4.3.1.

*Step 6.* For *i* from 3 to 23 the arithmetic average of the three adjacent slopes is computed as follows:

$$\bar{s}(i,k) = 1/3\left[s'(i,k) + s'(i+1,k) + s'(i+2,k)\right].$$

*Step 7.* The final one-third octave-band sound pressure levels, SPL"*(i, k)* is computed by beginning with band number 3 (or band number 1 for helicopters) and proceeding to band number 24 as follows:

$$SPL''(3,k) = SPL(3,k),$$
$$SPL''(4,k) = SPL''(3,k) + \bar{s}(3,k),$$
•
•
$$SPL''(i,k) = SPL''(i-1,k) + \bar{s}(i-1,k),$$
•
•
$$SPL''(24,k) = SPL''(23,k) + \bar{s}(23,k).$$

*Step 8.* The differences, $F(i,k)$ between the original sound pressure level and the final background sound pressure level are calculated as follows:

$$F(i,k) = SPL(i,k) - SPL''(i,k)$$

and only values equal to or greater than one and a half are noted.

*Step 9.* For each of the relevant one-third octave bands (3 to 24), tone correction factors from the sound pressure level differences *F(i,k)* and Table 1 are determined.

*Step 10.* The largest of the tone correction factors, determined in Step 9, as *C(k)* are determined.

Tone corrected perceived noise levels PNLT(*k*) shall be determined by adding the *C(k)* values to corresponding PNL(*k*) values, that is:

$$PNLT(k) = PNL(k) + C(k).$$

For any *i*-th one-third octave band, at any *k*-th increment of time, for which the tone correction factor is suspected to result from something other than (or in addition to) an actual tone (or any spectral irregularity other than aircraft noise), an additional analysis shall be made using a filter with a bandwidth narrower than one-third of an octave. If the narrow band analysis corroborates these suspicions, then a revised value for the background sound pressure level SPL"(*i, k*), shall be determined from the narrow band analysis and used to compute a revised tone correction factor for that particular one-third octave band.

## Maximum tone corrected perceived noise level

The maximum tone corrected perceived noise level, PNLTM, shall be the maximum calculated value of the tone corrected perceived noise level PNLT(*k*). It shall be calculated in accordance with the following procedure. To obtain a satisfactory noise time history, measurements shall be made at 500 ms time intervals.

*Fig. 1 is an example of a flyover noise time history where the maximum value is clearly indicated.*

*In the absence of a tone correction factor, PNLTM would equal PNLM.*

After the value of PNLTM is obtained, the frequency band for the largest tone correction factor is identified for the two preceding and two succeeding 500 ms data samples. The following test shall be applied to these four samples to identify the possibility of tone suppression by one-third octave band sharing of that tone. The frequency band of the maximum tone correction factor for the four samples is tested for a shift to lower frequencies (limited to three consecutive one-third octave bands) from the first to the fourth data sample. If the value of the tone correction factor *C(k)* for PNLTM is less than the average value of *C(K)* for the five consecutive time intervals the average value of *C(k)* shall be used to compute a new value for PNLTM.

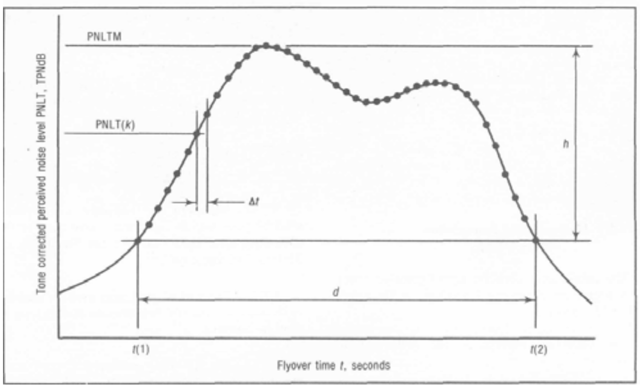



Fig. 1. **Example of perceived noise level corrected for tones as a function of aircraft flyover time**

## Duration correction

The duration correction factor *D* determined by the integration technique shall be defined by the expression:

$$D = 10\log\left[\left(\frac{1}{T}\right)\int_{t1}^{t2}\text{antilog}\frac{PNLT}{10}dt\right] - PNLTM\ ,$$

where *T* is a normalizing time constant, PNLTM is the maximum value of PNLT, *t*(1) is the first point of time after which PNLT becomes greater than PNLTM - 10 and *t*(2) is the point of time after which PNLT remains constantly less than PNLTM - 10.

Since PNLT is calculated from measured values of SPL, there will, in general, be no obvious equation for PNLT as a function of time. Consequently, the equation shall be rewritten with a summation sign instead of an integral sign as follows:

$$D = 10\log\left[\left(\frac{1}{T}\right)\sum_{k=0}^{d/\Delta t}\Delta t\cdot\text{antilog}\frac{PNLT(k)}{10}\right] - PNLTM\ ,$$

where $\Delta t$ is the length of the equal increments of time for which PNLT(*k*) is calculated and *d* is the time interval to the nearest 1.0 s during which PNLT(*k*) remains greater or equal to PNLTM – 10.

To obtain a satisfactory history of the perceived noise level, half-second time intervals for $\Delta t$, or a shorter time interval with approved limits and constants, shall be used.

The following values for *T* and *At* shall be used in calculating *D* in the procedure given above;

$$T = 10\ s \text{ and}$$

$$\Delta t = 0{,}5\ s\ .$$

Using the above values, the equation for *D* becomes

$$D = 10\log\left[\sum_{k=0}^{2d} \operatorname{antilog}\frac{PNLT(k)}{10}\right] - PNLTM - 13\ ,$$

where the integer $d$ is the duration time defined by the points corresponding to the values PNLTM – 10

If in the procedures given above, the limits of PNLTM – 10 fall between the calculated PNLT($k$) values (the usual case), the PNLT(&) values defining the limits of the duration interval shall be chosen from the PNLT($k$) values closest to PNLTM – 10.

## Effective perceived noise level

The total subjective effect of an aircraft noise event, designated effective perceived noise level, EPNL, shall be equal to the algebraic sum of the maximum value of the tone corrected perceived noise level, PNLTM, and the duration correction $D$. That is:

$$EPNL = PNLTM + D\ .$$

## Data reporting

The measured noisiness values of aircraft landing and taking-off are presented in Table 2. Maximum noisiness values are given in diagrams. Figs 2 and 3 show maximum sound levels at certain points of Boeing B-737 flyover at the fixed points: the aeroplane landing 102.2 dB at frequency 1744 Hz and taking-off, accordingly 95.6 dB at frequency 2256 Hz. Noise levels at the same points in one-third octave frequency are presented in Figs 4 and 5. It is seen from diagrams that noise propagated by Boeing B-737 is at the frequency range from 1000 to 2000 Hz. This means that this noise affects most of all the human hearing and nervous system.

Fig. 6 depicts a noise contour diagram at the Palanga Airport, produced according to the data, calculated with the help of a special computer program [2].

Each noise contour line shows the same sound level dB around the airport.

Table 2. **Table of aircraft noise measurement data**

| Measurement No. | Aeroplane type | Flight denomination | Perceived noise level | | |
|---|---|---|---|---|---|
| | | | Lateral | Flyover | Approach |
| 1. | JAK-40 | Landing | | | 75,9 |
| 2. | JAK-40 | Taking off | | | |
| 3. | JAK-40 | Landing | | | 88,1 |
| 4. | JAK-40 | Taking off | | 98,00 | |
| 5. | ATR-42 | Taking off | | | |
| 6. | ATR-42 | Landing | 84,3 | | 84,3 |
| 7. | B-737 | Landing | | | 102,2 |
| 8. | JAK-40 | Taking off | | 96 | |
| 9. | B-737 | Taking off | | 95,6 | |
| 10. | SAAB | Landing | | | 95,3 |
| 11. | SAAB | Taking off | | 80,0 | |
| 12. | SAAB | Taking off | | 81,0 | |
| 13. | B-737 | Landing | 81,1 | | |
| 14. | B-737 | Taking off | 93,6 | | |
| 15. | SAAB | Taking off | 82.8 | | |
| 16. | ATR | Taking off | | | |
| 17. | ATR | Landing | 58,0 | | |
| 18. | AN-2 | Landing | | | 59,8 |
| 19. | ATR | Landing | | | 66,4 |
| 20. | ATR | Taking off | | | |

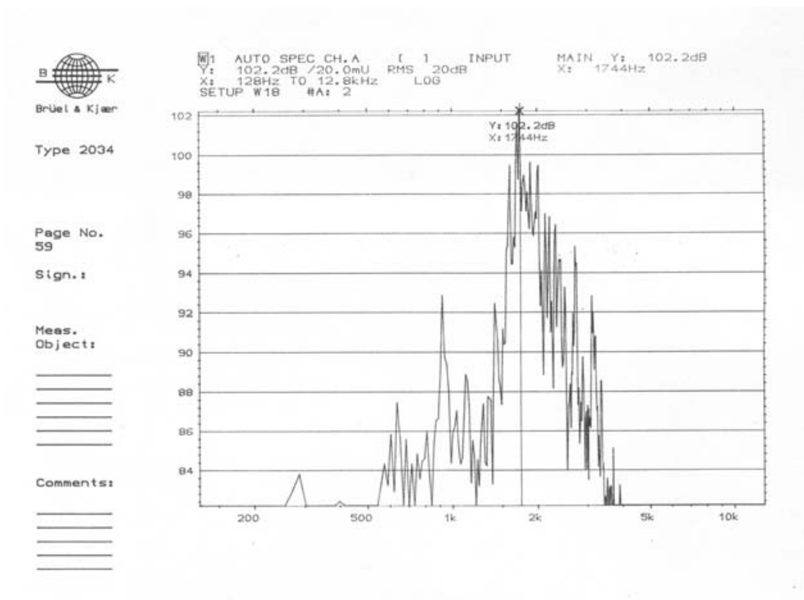



Fig. 2. **Maximum noise level continuous spectrum at point 7**

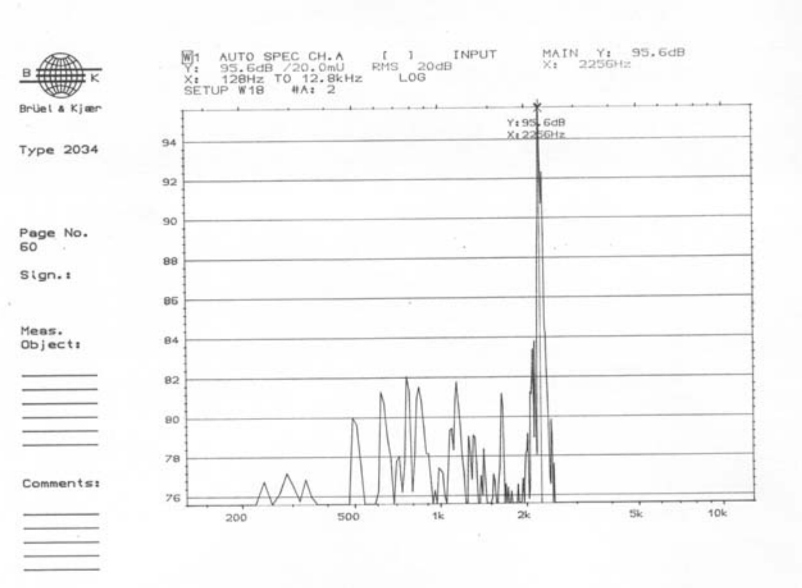



Fig. 3. **Maximum noise level continuous spectrum at point 9**

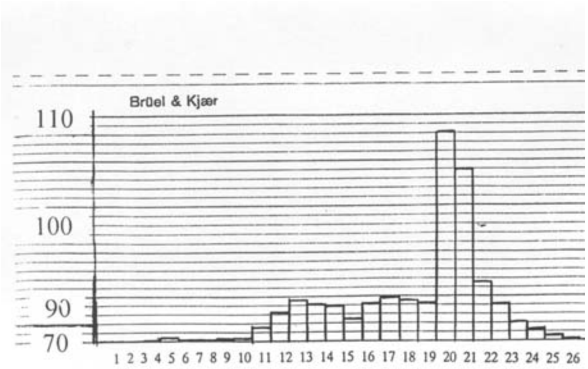



Fig. 4. **Maximum noise level spectrum of the flyover in one third octave frequency bands at point 7. Nominal frequency 1/3 octave No 1-25 Hz, 2-31,2 Hz, 3-40 Hz, 4-50 Hz, 5-63 Hz, 6-80 Hz, 7-100 Hz, 8-125 Hz, 9-160 Hz, 10-200 Hz, 11-250 Hz, 12-315 Hz, 13-400 Hz, 14-500 Hz, 15-630 Hz, 16-800 Hz, 17-1000 Hz, 18-1250 Hz, 19-1600 Hz, 20-2000 Hz, 21-2500 Hz, 22-3150 Hz, 23-4000 Hz, 24-5000 Hz, 25-6300 Hz, 26-8000 Hz**

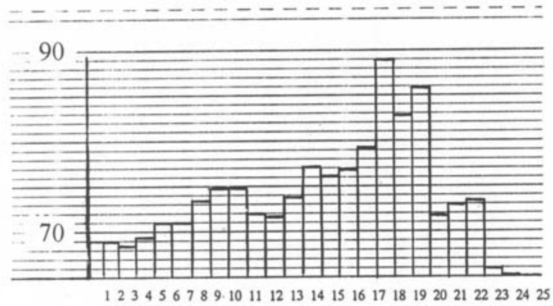



Fig. 5. **Maximum noise level spectrum of the flyover in one third octave frequency bands at point 9. Nominal frequency 1/3 octave No 1-25 Hz, 2-31,2 Hz, 3-40 Hz, 4-50 Hz, 5-63 Hz, 6-80 Hz, 7-100 Hz, 8-125 Hz, 9-160 Hz, 10-200 Hz, 11-250 Hz, 12-315 Hz, 13-400 Hz, 14-500 Hz, 15-630 Hz, 16-800 Hz, 17-1000 Hz, 18-1250 Hz, 19-1600 Hz, 20-2000 Hz, 21-2500 Hz, 22-3150 Hz, 23-4000 Hz, 24-5000 Hz, 25-6300 Hz**

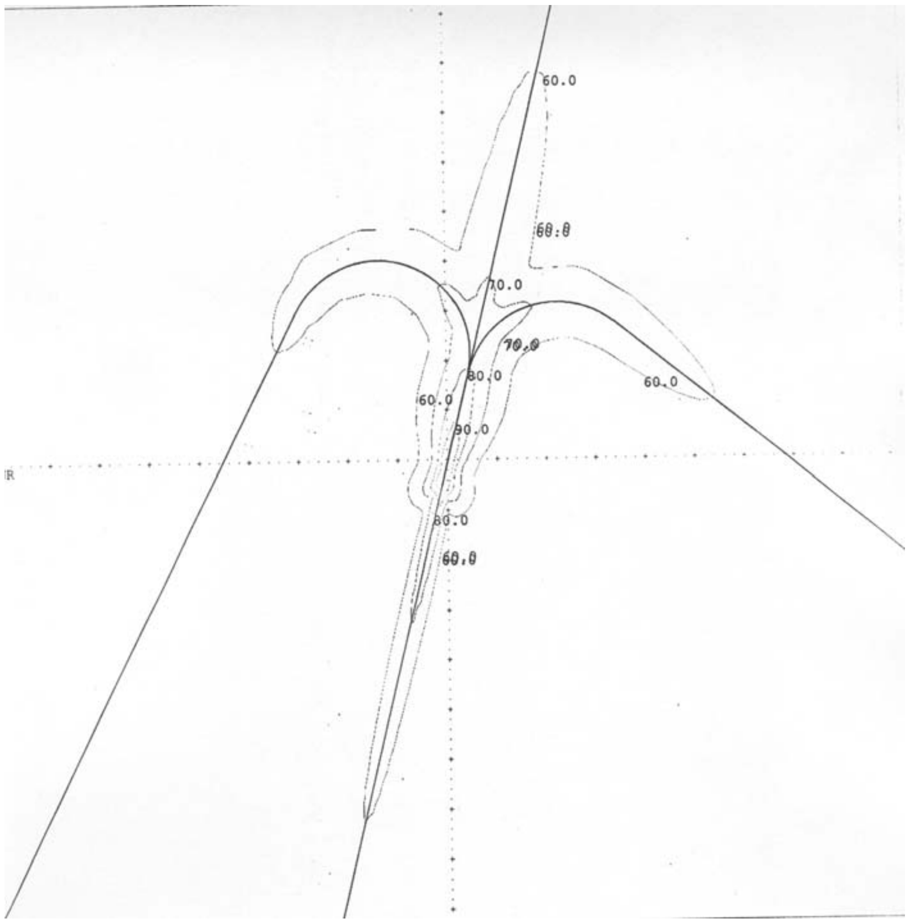



Fig. 6. **Diagram of noise contour at the Palanga Airport**

## Conclusions

1. The work presents primary aircraft noise measurements at the airport performed according to the ICAO and European standards.
2. Measurements results were processed according to the special program and methods with the help of the fixed "Brüel & Kjoer" apparatus.
3. According to the opportunities available and the exploratory results obtained, minute analytical noise spectra in real time at the measurement points are drawn.
4. According to the highest noise level fixed in time, spectra in one third octave, permitting to characterize noise of the aeroplane of the given type and its level, are drawn.
5. According to the international computer calculation program, recommended by ICAO, calculations of noise contours were performed and airport noise contours were drawn.

## Symbols and units

| *Symbol* | *Unit* | *Meaning* |
|---|---|---|
| *C(k)* | dB | *Tone correction factor*. The factor to be added to PNL*(k)* to account for the presence of spectral irregularities such as tones at the *k*-th increment of time. |
| *d* | *s* | *Duration time.* The length of the significant noise time history being the time interval between the limits of $t(1)$ and $t(2)$ to the nearest second. |
| *D* | dB | *Duration correction.* The factor to be added to PNLTM to account for the duration of the noise. |
| EPNL | EPNdB | *Effective perceived noise level.* The value of PNL adjusted for both the spectral irregularities and the duration of the noise. (The unit EPNdB is used instead of the unit dB.) |
| *f(i)* | Hz | *Frequency*. The geometrical mean frequency for the *i*-th one-third octave band. |

| | | |
|---|---|---|
| $F(i,k)$ | dB | *Delta-dB*. The difference between the original sound pressure level and the final background sound pressure level in the *i*-th one-third octave band at the *k*-th interval of time. |
| $n$ | noy | *Perceived noisiness*. The perceived noisiness at any instant of time that occurs in a specified frequency range. |
| $n(i,k)$ | noy | *Perceived noisiness*. The perceived noisiness at the k-th instant of time that occurs in the *i*-th one-third octave band. |
| $n(k)$ | noy | *Maximum perceived noisiness*. The maximum value of all of the 24 values of $n(i)$ that occurs at the *k*-th instant of time. |
| $N(k)$ | noy | *Total perceived noisiness*. The total perceived noisiness at the *k*-th instant of time calculated from the 24-instantaneous values of $n(i,k)$. |
| PNL | PNdB | *Perceived noise level*. The perceived noise level at any instant of time. (The unit PNdB is used instead of the unit dB.) |
| PNL($k$) | PNdB | *Perceived noise level*. The perceived noise level calculated from the 24 values of SPL($i,k$) at the *k*-th increment of time. (The unit PNdB is used instead of the unit dB.) |
| PNLM | PNdB | *Maximum perceived noise level*. The maximum value of PNL($k$). (The unit PNdB is used instead of the unit dB.) |
| PNLT | TPNdB | *Tone corrected perceived noise level*. The value of PNL adjusted for the spectral irregularities that occur at any instant of time. (The unit TPNdB is used instead of the unit dB.) |
| PNLT($k$) | TPNdB | *Tone corrected perceived noise level*. The value of PNL($k$) adjusted for the spectral irregularities that occur at the *k*-th increment of time. (The unit TPNdB is used instead of the unit dB.) |
| PNLTM | TPNdB | *Maximum tone corrected perceived noise level*. The maximum value of PNLT($k$). (The unit TPNdB is used instead of the unit dB.) |
| $\mathrm{PNLT}_r$ | TPNdB | *Tone corrected perceived noise level* adjusted for reference conditions. |
| $s(i,k)$ | dB | *Slope of sound pressure level*. The change in level between adjacent one-third octave band sound pressure levels at the *i*-th band for the *k*-th instant of time. |
| $s'(i,k)$ | db | *Adjusted slope of sound pressure level*. The change in level between adjacent adjusted one-third octave band sound pressure levels at the *i*-th band for the *k-th* instant of time. |
| $\bar{s}(i,k)$ | db | *Average slope of sound pressure level*. |
| *SPL* | dB re 20µPa | *Sound pressure level. The sound pressure level at any instant of time that occurs in a specified frequency range.* |
| $SPL(i,k)$ | dB re 20µPa | *Sound pressure level*. The sound pressure level at the k-th instant of time that occurs in the *i*-th one-third octave band. |
| $SPL''(i,k)$ | dB re 20µPa | *Final background sound pressure level*. The second and final approximation to background sound pressure level in the *i*-th one-third octave band for the *k-th* instant of time. |
| $t$ | *s* | *Elapsed time*. The length of time measured from a reference zero. |
| $\Delta t$ | *s* | *Time increment*. The equal increments of time for which PNL($k$) and PNLT($k$) are calculated. |
| $T$ | *s* | *Normalizing time constant*. The length of time used as a reference in the integration method for computing duration corrections, where $T = 10$ s. |

**References**


1. International Standards and Recommended Practices. Environmental protection. Annex 16. Volume 1. Aircraft noise. Third Edition. 1993.
2. Federal Aviation User's Guide. Integrated Noise Model, 1995.


D. Gužas

**Palangos oro uosto lėktuvų skleidžiamo triukšmo įvertinimas**

Reziumė

Straipsnyje nagrinėjama oro uostų lėktuvų keliamo triukšmo problema. Darbo tikslas - remiantis tarptautinio standarto, nurodyto literatūros sąraše, metodika, sudaryti Palangos oro uosto triukšmo kontūrų schemą ir ištirti maksimalius atskrendančių ir išskrendančių lėktuvų triukšmo lygius. Išmatuoti triukšmo lygiai apdoroti laboratorijoje ir rezultatai pateikti grafikuose. Kaip pavyzdį šiame straipsnyje pateikiame 7 ir 9 taškuose (žr. 2 lentelę) atliktų matavimų ir apdorotų rezultatų grafikus. Remiantis gautais lėktuvų triukšmo matavimo rezultatais, sudaryta Palangos oro uosto triukšmo kontūrų schema.

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