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# IDENTIFICATION TASK FOR ACOUSTIC MODEL OF AIRCRAFT AND ENGINE NOISE TESTING RESULTS

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**ABSTRACT**
Strict requirements to the accuracy and reliability of aircraft noise computation results provide for use of more complicate acoustic models of aircraft of various types. Previously it was proposed to solve the identification task for improvement of these models. Now it is shown how to use the results of engine noise testing (just before their implementation on aircraft) for improvement of the models that don't need the flight measurements. The efficiency of the method is proofed by comparison between different approaches.

## 1 - INTRODUCTION

The purpose of noise certification of the aircraft is to prove its accordance to requirements of current standards. These procedures are indispensable requirements for new aircrafts, implemented in operation and for successful adjustment of environment protection problem in a vicinity of airports [1,2]. Certification procedures and effectiveness estimations can be improved by the usage of worked up models and methods [3,4]. Among tasks, for decision of which the these models are most suitable, the following:

- developing and grounding of equivalent aircraft noise certification methods [2];
- bringing of aircraft certification and/or engine testing results to flight operation conditions, their usage in environment impact assessment;
- estimation of effectiveness of new aircraft implementation in a vicinity of airport under consideration or inside the whole region or nation-wide.

Equivalent methods are used to prove the accordance of aircraft type modifications, if the certification of a basic aircraft prototype were carrying out in a full volume and acoustic characteristics of the aircraft were fully defined − not only the levels in noise control points, but NPD-relationships (relationships of "Noise-Power-Distance" type) also for full range of operational modes and distances. This task can be solved with maximum accuracy by use of worked up models and methods with following algorithm (in brackets there are stated appellations of software used for particular task solving):

1. determination of directivity angle of maximum noise radiation for aircraft flight path;
2. computation of spectral characteristics of basic acoustic sources of the aircraft;
3. solving the task of identification of acoustic aircraft model [4];
4. computation of NPD-relationships for all range distances and engine modes for aircraft under consideration.

## 2 - ACOUSTIC MODELLING WITH FLIGHT DATA

The proof of worked up approaches and used algorithms for solving of aircraft noise certification tasks realized on example of noise analysis of Iljushin-86 aircraft, construction of its acoustic model using flight data of a given aircraft type and using the data of ground testing of aircraft engines HK-86, following estimation of NPD-relationships for Iljushin-86, and their use for the purposes of noise certification. The results of identified acoustic aircraft model for Iljushin-86 due to the flight data were investigated (identification of transmission function – $\Delta SPL_{TF}$) are shown on fig. 1 for maximum and nominal engine modes.

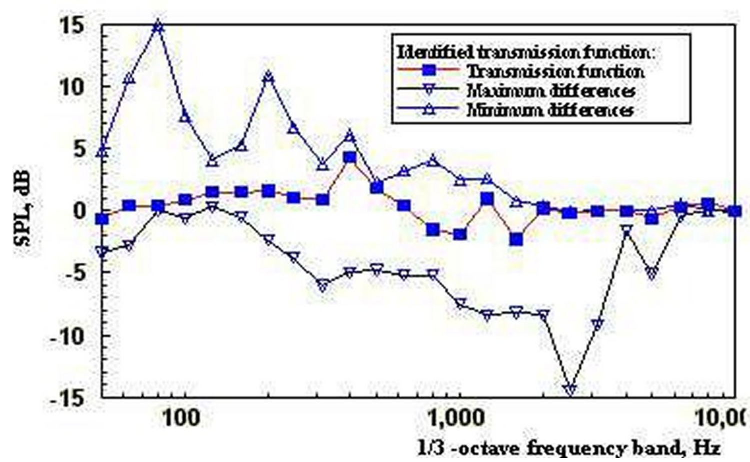


**Figure 1:** Identified transmission function for acoustic model of Iljushin-86 due to aircraft flight testing.

An identified acoustic aircraft model was used for computation of NPD-relationships. The results are taken in tabl. 1 for comparison with results of flight acoustic data.

| Flight height, m | Maximum engine mode EPNL, EPNdB | | | Nominal engine mode EPNL, EPNdB | | |
|---|---|---|---|---|---|---|
| | Calculated for identified model | Calculated with zero $\Delta SPL_{TF}$ | Measured | Calculated for identi-fied model | Calculated with zero $\Delta SPL_{TF}$ | Measured |
| 300.0 | 115.4 | 111.9 | 115.0 | 107.7 | 108.0 | 107.6 |
| 400.0 | 113.2 | 110.2 | 113.0 | 105.7 | 106.2 | 105.7 |
| 500.0 | 111.6 | 108.8 | 111.0 | 104.2 | 104.5 | 104.2 |
| 600.0 | 110.4 | 107.9 | 109.8 | 103.0 | 103.4 | 102.9 |
| 700.0 | 109.2 | 106.7 | 109.0 | 101.9 | 102.3 | 102.0 |
| 800.0 | 108.3 | 105.9 | 108.4 | 100.9 | 101.3 | 101.4 |
| 900.0 | 107.6 | 105.2 | 107.8 | 100.1 | 100.6 | 101.0 |

**Table 1:** NPD-relationships of Iljushin-86 due to aircraft flight testing.

Range of flight heights 300-900 m, used during flights, is insufficient for construction of NPD-relationships. Recommended range is limited by values 80-8000 m [2]. In accordance with [2] for range above overhead investigated height limit (H=800-900 m), noise levels are determined by extrapolation in dependence to noise level at H=800 m with account for divergence $L_R$ and atmosphere attenuation $L_{ATM}$ of noise, for example, as for $L_{AE}$:

$$L_{AE} = L_{AMAX} + (L_{AEH} - L_{AMAXH}) + 7.5\lg(d/800) \quad (1)$$

where $d$ – minimum distance from control point to flight path (approximately equal to flight height H), sound levels with index "H" correspond to measured values, $L_{AMAX}$ – extrapolated value at distance $d$:

$$L_{AMAX} = 10\lg\left(\sum 10^{(Lj - dLa)/10}\right); \quad Lj = Lj_H - \Delta L_R - \Delta L_{ATM} \quad (2)$$

In fig. 2 extrapolated by formula (1) dependence $EPNL=f(d)$ is brought in comparison with dependences, calculated with worked up algorithm and program RADIUS_N for extrapolated by formula (2) spectrum and by program RADIUS for identified acoustic aircraft model Iljushin-86 (for conditions of sound-waves reflection from grass covering of the reflecting surface).

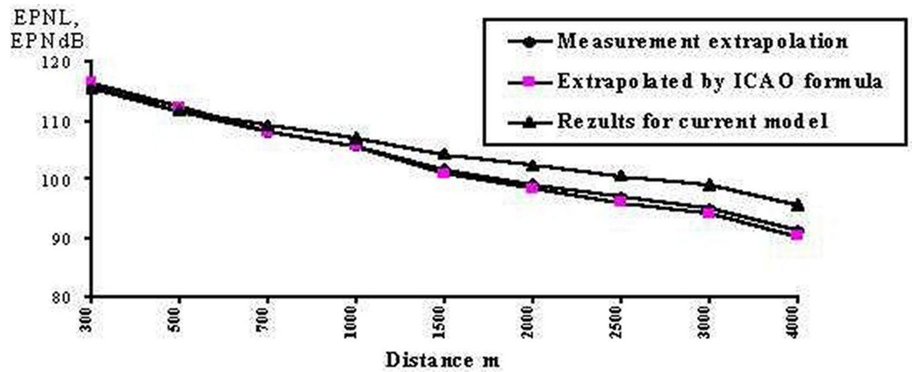


**Figure 2:** Comparison of NPD-relationships of Iljushin-86 aircraft defined by various models.

The extrapolated data do not take into account influence of "lateral noise attenuation" and considerably differ from computation results on worked up algorithm, peculiarly far away from control point.
Algorithm for estimation of certificated noise level in control point is worked up using calculated NPD-relationships. For these purposes it is necessary to define an engine mode, conforming to requirements of minimum permissible climbing gradient, and distance $d$ from control point to flight path. In accordance with data of aircraft flight investigations for Iljushin-86 with maximum weight 210 tons the permissible engine cut-off and permissible climbing gradient 4% are defined by to relative frequency of high pressure compressor 87,5% (engine mode − 0,9 nominal). Distance $d$ defined by flight data is equal to 300 m. Like so, noise level in control point equal to 107,6 EPNdB. Result of certification of the Iljushin-86 for given control point is 107,4±0,6 EPNdB, that confirm the possibility to use NPD-relationships for estimation of noise levels in accordance with certification requirements.

## 3 - ACOUSTIC MODELLING WITH ENGINE NOISE TESTING DATA

Results of static aircraft engine noise testing have been used also for construction of acoustic aircraft model, estimation of its NPD-relationships and determination of noise levels, conforming to certification conditions. They have specific peculiarities in comparison with flight investigations, and above all things − this is a lack of flight speed influence of acoustic sources on generated noise levels. A branch standard regulates hardly the noise measuring conditions at testing facility. Two installation heights of microphones ($h_r$=4,5 and 0,5 m) were used for apportionment of interference influence of direct and reflected sound waves. Maximum interference (first minimum) effect in accordance with simplified formula $f_0 = Ra_0/(4h_S h_R)$ locates at frequencies 420 Hz for microphone height 4,5 m and 3780 Hz for $h_R$ =0,5 m. Averaging of engine noise spectra performed for frequencies <800 Hz for data received at height 0,5 m, for frequencies > 3500 Hz − on data for height 4,5 m, between frequencies 800<$f$<3500 Hz − for both descriptions. Identification was realized with analogous algorithm [4] with the purpose to determine transmission function $\Delta SPL_{TF}$ using engine noise testing data. On fig. 3 $\Delta SPL_{TF}$ for maximum and nominal engine modes are shown. The identified acoustic models were used for NPD-relationships computation for maximum and nominal engine modes (tabl. 2). Data from 2 and 4 columns of the tabl. 2 with high exactness compare with results of tabl. 1, as with measured, so as with calculated values (for identified acoustic model using flight noise data). Like so the possibility to use the results of aircraft engine noise testing for construction of acoustic aircraft models and determination of noise certification data for explored aircraft is proved.

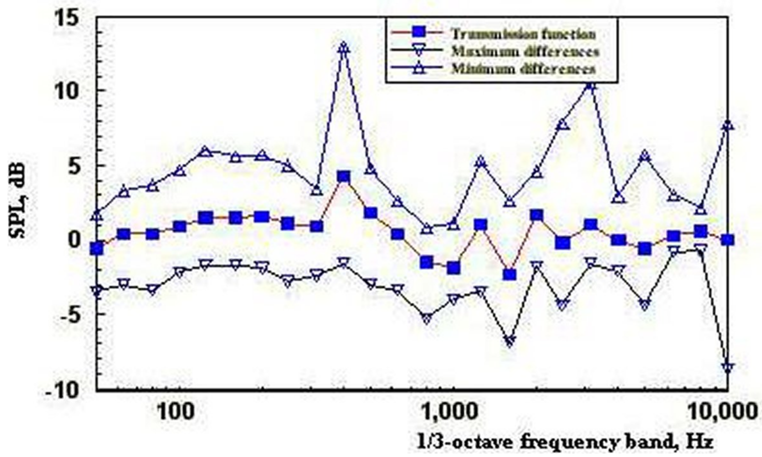


**Figure 3:** Identified transmission function for acoustic model of Iljushin-86 due to aircraft engine noise testing.

| Flight height, m | Maximum engine mode, EPNdB | | Nominal engine mode, EPNdB | |
|---|---|---|---|---|
| | $\Delta SPL_{TF}$ for maximum mode | $\Delta SPL_{TF}$ for nominal mode | $\Delta SPL_{TF}$ for nominal mode | $\Delta SPL_{TF}$ for maximum mode |
| 300.0 | 115.4 | 114.2 | 108.0 | 109.4 |
| 400.0 | 113.4 | 112.1 | 106.0 | 107.5 |
| 500.0 | 112.0 | 110.7 | 104.6 | 106.1 |
| 600.0 | 110.8 | 109.5 | 103.4 | 105.0 |
| 700.0 | 109.6 | 108.3 | 102.4 | 104.0 |
| 800.0 | 108.8 | 107.2 | 101.4 | 103.2 |
| 900.0 | 107.8 | 106.3 | 100.6 | 102.4 |

**Table 2:** NPD-relationships computed for Iljushin-86 aircraft.

In real operational conditions the aircraft flight procedures differ from certification flight procedures, in particular during take-off and/or climbing. Adduction of aircraft noise certification results to operational data performs using two groups of parameters: flights trajectories parameters and NPD-relationships. For example, in accordance with flight operation guide for aircraft Iljushin-86 with take-off weight 210 tons distance from control point N°2 [1] to the climbing trajectory puts together 330 m (an engines mode is maximum), flight speed is about 90 m/s. On NPD- relationships data from tabl. 2 these parameters correspond to noise level 114,5 EPNdB (cut-off effectiveness attached to comparison with certification flight procedure − by 7 EPNdB).

## REFERENCES


1. **Environmental protection, Aircraft Noise**, Annex 16 to the Convention on International Civil Aviation, Montreal, ICAO, Vol. 1, pp. 182, 1993

2. **ICAO Technical Guide for Environment Protection**, Montreal, ICAO, Doc. 9501−AN/929, ed. 2, pp. 112, 1995

3. **Tokarev, V.I., Zaporozhets, O.I., Straholes, V.A.**, *Noise Abatement for Passenger Airplanes in Operation* (in Russian), Tehnika, Kyiv, pp. 127, 1990

4. **Zaporozhets O.I., Tokarev V.I.**, Aircraft noise modelling for environmental assessment around airports, *Applied Acoustics*, Vol. 55(2), pp. 99-127, 1998