Analysis and Validation of „Rep-Zaj" – a Hungarian Developed Noise Simulating Software for Noise Mapping around Airports

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Budapest Ferihegy International Airport possesses a noise monitoring system that enables an accurate and detailed analysis of the noise situation around the airport. It is limited, however by the small number of microphones that constitute the sensing part of the system, and which are deployed in the vicinity of the aerodrome. Thus it was essential to develop a noise simulation software, a prediction tool, with the help of which the noise situation can be reliably calculated. The aim of this paper was to analyse and validate this noise prediction tool, as compared to a wider range of noise prediction softwares. In the first part of the paper the usage and the special features of the software are described, whereas the second part focuses on the validation procedure. Several SPL measures have been carried out at and around Budapest Ferihegy International Airport with a mobile noise measuring device, and the results have been used to validate the calculations of the noise simulating software. The main area of interest was the time history of noise measured and calculated at one specific point, but with the same measurement the noise contours of the maximum noise predicted by the software could also be evaluated. The first results show a relatively good correlation between the measured and the calculated data, the small differences may be due to the meteorological conditions. Future work could include development of the software and further validations incorporating the evaluation of the noise maps displaying equivalents sound levels.

1 Introduction

Budapest Ferihegy International Airport possesses a newly installed, modern noise monitoring system, comprising 6 microphones. These microphones measure noise recording sound pressure level from a given threshold, and calculating the equivalent and maximum noise levels. Due to the relatively small number of monitor points though it has become essential to develop a noise-simulating tool, with the help of which the noise situation can be described anywhere in the vicinity of the airport. In this paper we shortly describe the way this program operates, and then move on to its validation procedure. Carrying out several noise measurements around the aerodrome enabled us to compare the calculated noise maps with the empirical data.

2 The structure of "Rep-Zaj"

2.1 The idea behind this program

Software "Rep-Zaj" is a Hungarian noise-simulating program; its development began in 1978. Its final version was created in 2003. Basically it can be divided into two modules. First, the flight path of the aircraft is computed or alternatively it can be entered in the form of radar data. Secondly the noise source is moved along this path, and noise propagation is calculated.

The simulation of flight path is uniquely solved: the position of the aircraft is not given with vectors but with differential equations. This program also requires either pre-described or manually input noise data about the aircraft. Air absorption, directivity of source, the

$$m\left(\frac{d\bar{v}}{dt} + \bar{\omega} \times \bar{v}\right) = p$$

$$\frac{d\bar{\Pi}}{dt} + \bar{\omega} \times \bar{\Pi} = M$$

Where	$\bar{v}\,(v_x, v_y, v_z)$	is speed vector,
	$\bar{\omega}\,(\omega_x, \omega_y, \omega_z)$	angular velocity,
	$\bar{\Pi}$	angular momentum vector,
	$M\,(M_x, M_y, M_z)$	turning moment,
	P (X, Y, Z)	force vector,
	m	the mass of the airplane.

Figure 1: Equations describing the state of motion from a coordinate system (x,y,z) fixed to the airplane [1]

$$\frac{dv_x}{dt} = \omega_z v_y - \omega_y v_z + \frac{1}{m}(X+P) - g\sin\varphi_v$$

$$\frac{dv_y}{dt} = \omega_x v_z - \omega_z v_x + \frac{1}{m}Y - g\cos\varphi_v \cos\varphi_d$$

$$\frac{dv_z}{dt} = \omega_y v_x - \omega_x v_y + \frac{1}{m}Z - g\cos\varphi_v \sin\varphi_d$$

$$\frac{d\omega_x}{dt} = \frac{1}{J_x}\left[M_x + \omega_y \omega_z (J_y - J_z)\right]$$

$$\frac{d\omega_y}{dt} = \frac{1}{J_y}\left[M_y + \omega_z \omega_x (J_z - J_x)\right]$$

$$\frac{d\omega_z}{dt} = \frac{1}{J_z}\left[M_z + \omega_x \omega_y (J_x - J_y)\right]$$

Figure 2: The differential equations describing the state of motion component by component [1]

Doppler effect are all taken into account. Noise levels are calculated in every node of a pre-defined grid, results can be depicted in a user-friendly way, either as a noise map of maximum or equivalent noise levels, or as a time history of noise on a specific point. It is possible to measure the effect of not only one but several noise events [2].

2.2 Validation of "Rep-Zaj"

We carried out measurements at Budapest Ferihegy International Airport, recording the maximum and equivalent noise levels, and the time of flyover. An example of the results can be seen in Table 1. In this case the measurement point was located in 350 m-s distance from the runway, and the noise levels were recorded during take-off.

Table 1: Empirical noise data measured at Budapest Ferihegy International Airport

Type of aircraft	Max.		SEL	Time of Flyover	Leq
	L dB(A)	L dB(lin)	dB	s	dB(A)
Tu-154	90,1	91,2	96,5	11	86,1
Fokker	79,4	98,2	85,1	7,5	76,4
Fokker	79	85,2	86,7	13,5	75,4
Fokker	80,5	84,8	87,3	12	76,5
B737	86,3	91,5	93	10	83
B737	83,7	93,4	90,3	11	79,9
B777	84,9	90,5	91,5	11,5	80,9
SAAB 340	80,8	99,8	87,4	13,5	76,1
Learjet	78,5	85,9	86,4	19	73,6
B737	83,2	88,6	91,6	15	79,8
B737	86,4	92,1	93,2	12	82,4
Tu-154	103,5	107,8	112,3	15,5	100,3
Blackhawk	83	87,2	90,3	11	79,9
CRJ	74,1	85,9	91,9	14	70,5
B737	83,7	88,8	90,8	9	81,2
BAE 146	78,7	85,3	85,2	8,5	75,9
CRJ	76,8	83,5	82,4	9	72,9
B767	84,2	81,7	89,8	7	81,4
F70	84,1	87,7	90,6	8,5	81,3
B737	84,4	89,2	91,3	10,5	81,1
B737	86,9	91	82,7	7,5	82,7
F70	81,6	85,8	87,3	7,5	78,5
B737	85,7	89,6	91,5	10	81,5
B767	87,8	93,9	90,6	4	84,6

Using the results from the measurements we calculated noise levels characteristic for different types of aircraft.

In Table 2 you can see the results for point A and B for aircraft B 737.

Table 2: Measured results and their calculated average for specific points

B737	Max.	Total Time of Flyover	Calc. Time of Flyover	Leq	SEL
	dBA	s	s	dBA	dBA
A	86,3	48	10	83	93
	83,7	41,5	11	79,9	90,3
	83,2	28,5	15	79,8	91,6
	86,4	18,5	12	82,4	93,2
	83,7	23,5	9	81,2	90,8
	84,4	45,5	10,5	81,1	91,3
Average for A	84,8	34,25	11,25	81,4	91,8
B	86,9	41	7,5	82,7	82,7
	85,7	33,5	10	81,5	91,5
	84,7	32,0	11,4	81,3	91,8
Average for B	85,8	35,5	9,6	81,9	90,1

For both points I calculated the maximum noise levels for the take-off of a B 737 using program "Rep-Zaj". The points referred to as A and B are in the simulation:

Point A (X = 1350m, Y = 350m, H = 135m),

Point B (X = 1350m, Y = -350m, H = 135m).

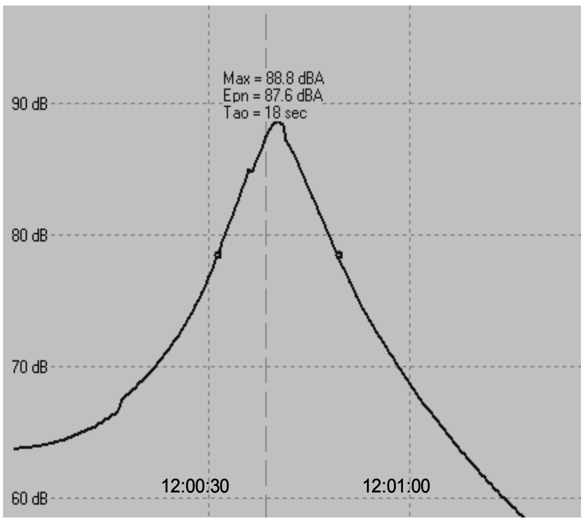


Figure 3: Simulation for point A – B 737 take-off

In Figure 3 you can see the simulation carried out for point A. The graph is also labeled with the maximum noise level, the equivalent noise level and the time of flyover (time interval between the two circles). In Figure 4 the result of an individual measurement of the same aircraft type, from location A can be seen. It is clearly visible, that the shapes of the graphs correlate well.

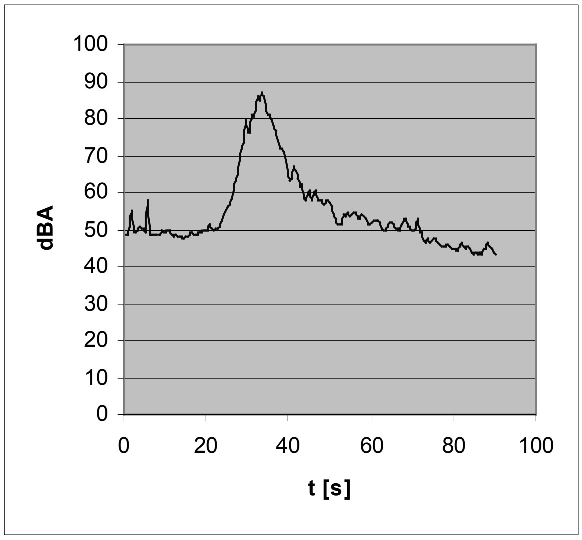
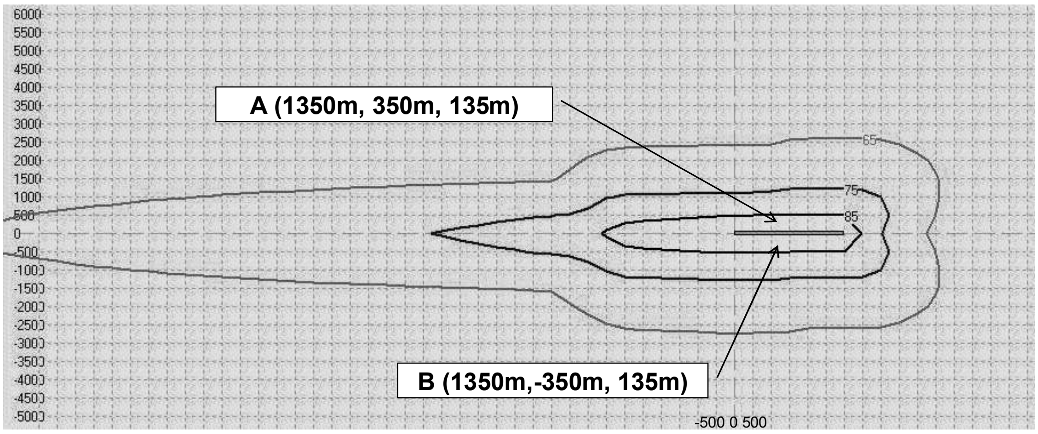


Figure 4: Time history of a B 737 take-off

Examining the maximum noise levels, it became evident, that there is relatively small difference between the maximum noise levels of the measured and the calculated data. This was true to all the other measured and calculated data-pairs. The small differences must have occurred due to the directivity of the noise source and meteorological conditions, which – in our first simulations – has not been taken into account. In the future we plan to investigate the correlation with directional noise sources.

We also calculated the noise map of maximum noise levels (Figure 5). The location of points A and B are shown. These results also correlate well with measured data. It is clear from above that program "Rep-Zaj" is capable of simulating the path of aircraft and their noise level at a specific point. Results have shown a relatively good correlation between the measured and the calculated data, the small differences may be due to the meteorological conditions. Future work could include development of the software and further validations incorporating the evaluation of the noise maps displaying equivalent sound levels.

Figure 5: Maximum noise levels calculated with "Rep-Zaj"



3 Summary

Noise is a factor that influences the every day life of those living around an airport. Being aware of the noise situation is a very important task of every airport. That is why a noise monitor has been installed at Budapest Ferihegy International Airport. Still, to be able to give estimates about future noise situations and predicting noise levels at those sites where microphones are not installed is equally important. For this reason there was an increased need for a noise simulating tool, with the help of which noise prediction becomes a reality.

"Rep-Zaj" is a Hungarian developed noise simulation program enabling the operator to give estimates about the future noise situation. It comprises two main parts: the module for the simulation of the flight path, and the module for the assessment of noise.

Several measurements have been carried out at Budapest Ferihegy International Airport to validate the noise simulation program. These measurements were grouped according to the aircraft type, and the same movements were simulated in "Rep-Zaj". Also noise maps of the maximum noise level have been created.

Results show that there is a relatively good correlation between the measured and the calculated data, both in the case of maximum noise levels, as in the case of noise maps depicting maximum noise levels. We plan to carry out future examinations to validate the noise maps of equivalent sound level.

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