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# COMMERCIAL AIRCRAFT NOISE ASSESSMENT AT LYON SAINT-EXUPÉRY INTERNATIONAL AIRPORT. IN FLIGHT SOURCE FREQUENCY CHARACTERISATION

*Simple noise level monitoring systems, which are currently used around airports to create a noise map in residential areas, are unable to identify source frequencies and their impact on the environment. This article presents the dominant frequencies during aircraft approaches at Lyon Saint-Exupéry International Airport (France) and analyzes the evidence of their impact on the environment. The results have the potential to contribute to the improvement of environmental quality around airports. They provide the emitted frequencies during the operations which can be treated by passive or active control systems.*

*Розглянуто системи контролю рівня шуму, що використовуються навколо аеропортів для створення карт шуму в житлових областях, але вони не можуть ідентифікувати початкові частоти і визначити їх вплив на навколишнє середовище. Подано домінуючі частоти протягом заходу літаків на посадку в Міжнародному аеропорту Сент-Екзюпері (Ліон, Франція). Проаналізовано їх вплив на навколишнє середовище. Результати вказують на потенціальну можливість поліпшення екологічної якості навколо аеропортів та на частоти випромінювання, з якими можна боротися пасивними або активними системами регулювання.*

## Introduction

Among environment concerns, excessive aircraft noise and its control has become a major objective of airport authorities.

Several procedures have been used in the worldwide aircraft operation such as low-noise during the take-off and landing flight procedures, optimal route distributions, flight route optimization around airports, etc.

Nevertheless, the noise in the vicinity of airports, in particular under the take-off and landing flight paths remains high disrupting the quality of life of local residents. Technology solutions and the positive measures taken by airport authorities have failed to reduce their impact near airports because of the growth in air traffic.

All the experts agree that around 2020, taking into account the known oilfields and the potential extraction, the production of oil will reach a maximum level and then decrease, especially with the growing economic power of China and India. Whatever the efforts to conserve energy and promote renewable energy, air transport will continue to grow, even with very expensive oil at the expense of other modes of transportation that will certainly be met by electricity.

This problem can only be solved within the framework of a global vision for sustainable development involving new technology of engines and fuselages, breakthrough technologies, the design of new procedures and flight paths [1; 2], airspace management, new regulation rules and certification.

In flight, commercial jet aircraft sources are active. Their relative importance depends on the flight segment and the airframe-engine combination. The objective of this work is the characterization of the dominating frequencies defined by the most raised levels and which could be treated by the aeronautical manufacturers.

## Experimental set up

The measurement campaign of aircraft noise approaching Lyon Saint-Exupéry International Airport lasted one year. It was used as a reference year because of changes in the airport infrastructure project (two new runways …) and the predictable fleet renewal.

During one year, the aircraft noise signals were recorded according to annex 16 of the ICAO convention [3; 4].

The data were recorded at four observation points: under flight path at 2 km, 2 km ± 400 m lateral, and lateral to a 1600 m runway and 500 m from the touch axis.

The two lateral reception points were used to make an adjustment on the data especially, when the trajectories practiced during the approach deviate from the main axis of the runway due to a change in the runway landing.

Measurements were performed under the checked stable atmospheric conditions (ambient air temperature, relative humidity, wind speed, cloudiness and global radiation).

A SIP 95 sound level meter, a Symphony 01dB-Stell© station, and a DAT FOSTEX PD-4 were used to record the acoustic data.

The four microphones are positioned at 4 m above the ground to comply with the requirement of free fields.

The ground is flat and consists of short grass without brush, wood or obstacles.

Calibrations are performed every day.

Irregularities which occur in measured spectra due to interference effects have been identified and corrections are applied to spectral characteristics which are not related to aircraft noise source. As specified in appendix 2 of the ICAO Annex 16, narrow band analysis is a recommended procedure for identifying the tones. Thus, we identified and retained 15460 turbojet aircraft executing approaches of the airport in the same conditions among 84.5 % (+20 T) equipped by turbojet engines which land at the airport. 15 % of the traffic represents propeller aircraft (3–9 T and +20 T) and 0.5 % other (-3 T and 3-9 T).

Propeller aircraft were excluded in this analysis because difficulties appear on all the levels of the harmonic frequencies. The time and frequency signals are analyzed by DBTrait© software and by specific algorithms developed in a Matlab© / C++© taking into account the spectral characteristics of the recorded signals.

**Results and discussion**

The study of dominant frequencies emitted during operations is important because it should allow manufacturers to focus their R&D on improving the sound-proofing of aircraft noise active and passive systems.

This study also helps to make a diagnosis of frequencies that contribute more to the discomfort of residents around airports.

Another advantage of this research is to reduce the computational time of noise propagation models often conducted in a wide frequency band.

Knowing the frequencies recorded at the receiver, we can assess the frequencies emitted by aircraft sources according to the emission angle θ and the indicated aircraft speed.

To remove Doppler Effect, we have used analysis by Miyara et al. [5]. At the reception point, the observed frequency $f_d$ can be written as:

$$f_d = \frac{1-\frac{V_w}{c}\cos(\theta+3)}{1-\frac{V_w}{c}\cos(\theta+3)-M.\cos(\theta)} f ,$$

where

$V_w$ is the wind speed;

$M$ is mach number:

$$M = \frac{V}{c};$$

$V$ and $c$ are respectively the speed of the aircraft and the sound;

$f$ is the engine frequencies.

In order to obtain V, we used the following expressions:

for a lateral distance x ~ +∞, then the observed frequency

$$f_{+\infty} = \frac{c-V_w}{c-V_w-V\cos(\alpha)} f_+$$

and for x ~ -∞, then the observed frequency

$$f_{-\infty} = \frac{c+V_w}{c+V_w+V\cos(\alpha)} f_- .$$

With $f_+ \cong f_- \cong f$ the main engine frequency,

$$V = \frac{c-V_w}{\cos(\alpha)}\left[\frac{f_{+\infty}-f_{-\infty}}{\frac{c-V_w}{c+V_w}f_{-\infty}+f_{+\infty}}\right],$$

where

$\alpha = 3°$;

$f_{-\infty}$ is the observed frequency before the aircraft over flight and $f_{+\infty}$ after the over flight.

Because aircraft noises are considered as unsteady states, the Wigner-Ville time-frequency distributions are applied to time-series data [6]. It is defined as [7]:

$$WV(t,f) = \int_{\infty} s(t+\frac{\tau}{2})s^*(t-\frac{\tau}{2})e^{-2j\pi f\tau}d\tau ,$$

where

$s$ is the signal time measurements and s* the complex conjugate.

The instantaneous frequency is assessed by the marginal moment and its dual by the group delay

$$\frac{\int_{\infty} t * WV(t,f)dt}{\int_{\infty} WV(t,f)dt} .$$

Two major components in ground-perceived aircraft noise are revealed: broadband noise and some tonal components. An automatic search of maximum levels was achieved and pure frequencies and frequency bands were found. Identification and counting were carried out. After normalization, we obtained the result shown in fig. 1 representing the third octave bands associated to the highest noise levels.

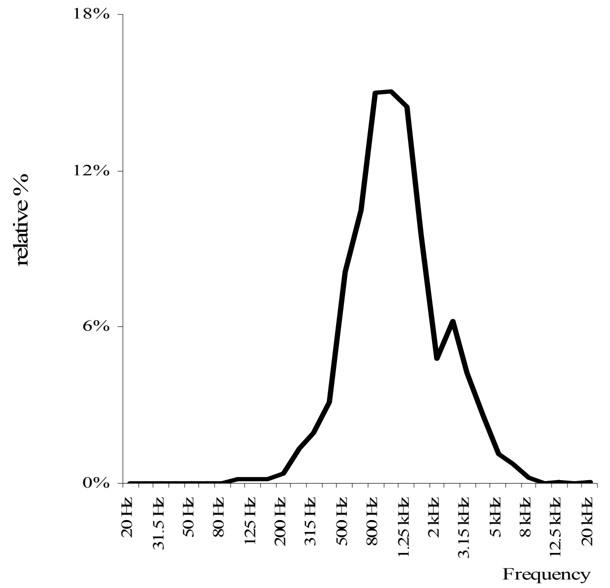


Fig. 1. The dominant third octave bands

The major observed bands are 630 Hz, 800 Hz, 1000 Hz, 1250 Hz and 1600 Hz whose noise levels are the highest. The third-octave bands 1.25 kHz and 1.6 kHz are dominant. Their origin could be either the airframe or engines, particularly the combustion chamber and the turbines that are emitting broadband sounds between 1500 Hz and 5000 Hz.

The dominated pure frequencies emitted by aircraft sources, corrected for the Doppler effect were assessed for speeds between 56 m/s to 150 m/s. These are the frequencies 800 Hz, 1000 Hz, 1142 Hz and 3500 Hz (fig. 2).

Their maximum intensities and their width at half height are: 800 Hz (77 dB, 32 Hz), 1000 Hz (75 dB, 38 Hz), 1142 Hz (79 Hz, 38 Hz) and 3500 Hz (62 dB, 34 Hz). The frequency 1 kHz observed was highlighted by Cremezi [8] and by Miyara et al. [5].

The frequency 3500 Hz is the whistling noise emitted by the fan. This noise, known to aircraft manufacturers, accounts for up to 7 % of the noise on approach. However, we have no explanation for the observed frequency 1142 Hz. It could originate from the engines. Certain frequencies were not observed. They correspond to the low frequency noise (50 Hz - 500 Hz) which may occur under certain weather conditions and engine operations.

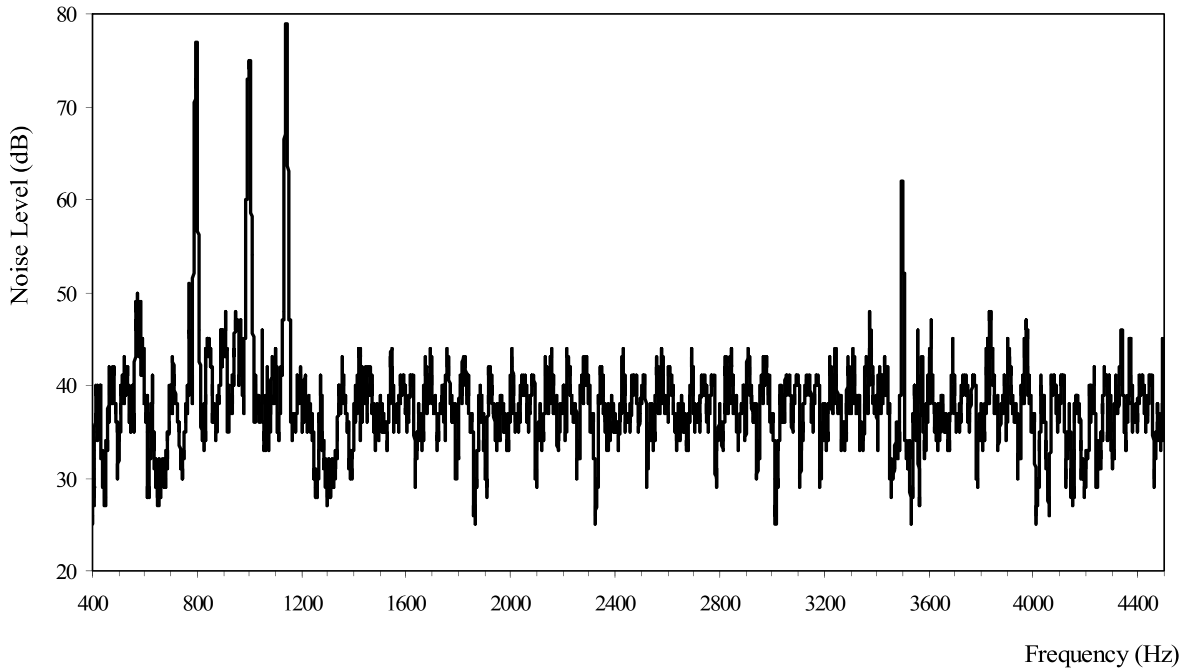


Fig. 2. Spectral analysis showing dominant frequencies

## Conclusion

This research establishes both the dominant frequencies and the aircraft passage times when approaching the airport. It provides aircraft manufacturers with some answers regarding the frequencies emitted during the landing phase, whilst it also allows for precise diagnosis as to frequency and pure frequency bands responsible for the noise annoyances surrounding this airport. These frequencies may originate in the airframe of the aircraft which upon landing has an engine rpm at idle of up to 55 %, for some aircraft can have a higher contribution from 10 dB above the noise of the engine, or engines, particularly the combustion chamber and turbine emitting broadband noise. Additional research is required in order to determine the effect of different aircraft on the given results and to analyze, in particular, the frequencies emitted by commercial propeller aircraft.

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**References**

1. *Zaporozhets O. I., Tokarev V. I.* Predicting Flight Procedures for Minimum Noise Impact. Applied Acoustics. – 1998. – Vol. 55, No 2. (Great Britain.)

2. *Zaporozhets O. I.*, *Khardi S.* Optimisation of aircraft trajectories as a basis for noise abatement procedures around the airports. Theoretical considerations and acoustic applications. Les collections de l'INRETS. Rapport INRETS n° 257. juillet 2004. – 97 p.

3. *ICAO* Recommended method for the calculation of the noise level contours in the vicinity of airports. Circular 205-AN/1/25. Intern. Civil Aviation Organization. – 1988.

4. *Montreal*, Canada. ICAO. Environment protection. – 2004. – Vol. 1: Aircraft noise – specifications for aircarft noise certification, noise monitoring, and noise exposure units for landuse planning.

5. *The acoustical* geometry of aircraft overflights / C. Miyara, S. Cabanellas, P. Mosconi et al. // Intern. Congr. and Exhibition on Noise Control Engineering. Tha Hague (Nl.), August 27–30. 2001.

6. *Biscainho L.W.P., Diniz P.S.R., Esquef P.A.A.* ARMA processes in sub-bands with application to audio restoration // Proc. of IEEE Intern. Symposium on Circuits and Systems. – Sidney 2. – 2001. – Pp. 157–160.

7. *Baraniuk R.G., Jones D.L.* A signal-dependent time-frequency representation: optimal kernel design // IEEE Trans. on Signal Processing. – 1993. – Vol. 41, No 4. – Pp. 1589–1602.

8. *Cremezi C.* Etude de la propagation du son dans l'atmosphère : application au bruit des avions en phase d'approche et de décollage. Thèse de Doctorat. – 2000.

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