Proceedings of The Institute of Acoustics

# LATERAL NOISE ATTENUATION

R.F. LAMBERT AND P. EVANS

ENGINEERING SCIENCES DATA UNIT LTD, LONDON

## 1. INTRODUCTION

The increased use of noise contours and footprints to control both aircraft movements and land-use planning in the vicinity of airports emphasises the need for a reliable prediction method for these contours. An important component in the prediction of noise contours is the estimation of the attenuation of sound as it propagates close to the ground plane. To increase our understanding of the factors which influence lateral sound attenuation ESDU have been working in collaboration with the Society of Automotive Engineers (SAE) on the analysis of aircraft flyover noise data. This work is not yet complete so this paper describes the analysis of the data and gives a report on the progress to date.

For the purpose of this paper lateral attenuation is defined as the difference between the under-the-flightpath and sideline free-field sound levels where the propagation range of the two sound levels is the same. The sound levels used are for the same noise radiation angle and the same aircraft flight conditions (configuration, engine thrust setting, etc.). This broad definition of lateral attenuation includes the effects of source installation and atmospheric effects such as refraction of the sound wave due to wind and temperature gradients and attenuation due to atmospheric turbulence. The source installation effects include airframe shielding, reflections from the airframes, jet-on-jet shielding and vortex effects.

By analysis of carefully controlled tests in steady stable atmospheric conditions the effects of wind and temperature gradients, and atmospheric turbulence, are reduced to a minimum. Also by analysing spectra over a range of noise emission angles an assessment of the influence of source installation effects can be made. The objective of the first stage of the analysis is to provide lateral attenuation data in terms of the basic parameters (frequency, range and elevation angle) for aircraft of particular engine/airframe configurations. Further investigation of installation effects may then allow the collapse of these data to a single lateral attenuation prediction for all aircraft.

## 2. GROUND REFLECTION CORRECTION

The effects of ground reflections on a typical under-the-flightpath and sideline spectra measured by microphones 1.2 m above the ground are shown in Figure 1. These spectra are the ground reflection correction spectra for equal sound propagation distances. It is evident that subtraction of spectra contaminated by these ground reflection effects will give rise to spurious values of lateral attenuation. In any investigation of the dependence of lateral attenuation on sound frequency it is therefore essential to first remove the effects of ground reflections so converting the spectra to free-field conditions.

The method of removal of the effects of reflections are based on the theory in Reference 1. In this theory the impendance of the ground surface is calculated using a porous absorber model. The normal-incidence acoustic impedance and the propagation coefficient can be characterised in terms of the specific flow resistance per unit thickness and a porosity factor. For all practical purposes it has been found that the porosity factor may be set to unity so that the ground impedance can be represented using only the flow resistance parameter.

In practice it is often found that the calculated frequency of the first minimum in the ground reflection spectrum does not coincide with that frequency in the measured spectrum. This discrepancy may result from the non-homogeneity of the atmosphere or, in the case of aircraft flyover noise, tracking errors lead to the calculation of the frequency of the first ground reflection minimum being based on an error in source location. In correcting the measured free-field spectra the predicted ground reflection corrections are aligned with those in the measured spectrum.

A further correction is applied to the estimated ground-reflection spectrum to account for the characteristic of the filter used in the analysis of measured data. Without this correction there is a tendency to overpredict the correction due to ground-reflection, especially around the band containing the first ground-reflection minimum frequency and its first pseudo-harmonic.

A full description of the procedure to correct measured noise spectra for the effects of ground reflections is given in Reference 2.

## 3. LATERAL NOISE ATTENUATION

Values of lateral attenuation are estimated on each of the one-third octave frequency bands for the full range of frequencies measured. These values of lateral attenuation will be correlated against elevation angle, frequency and propagation distance in order to develop an empirical prediction method for lateral attenuation.

The steps in the analysis procedure are as follows.

(a) Relate the source location to the aircraft tracking point and decide whether multiple sources are needed in the analysis.

For some multi-engined aircraft where the sound propagation range is small it is necessary to consider each engine as a separate noise source. For ranges greater than 70 m it is generally acceptable to assume a point source on the aircraft centre line.

(b) Estimate the source position at the time of emission, for both under-the-flightpath and sideline locations, for the radiation angle considered, and select the appropriate measured spectra.

(c) For each flyover height calculate the under-the-flightpath ground reflection spectrum and correct the measured spectra to free-field conditions.

(d) For the under-the-flightpath free-field spectra calculate the reference spectrum for the radiation angle considered.

The reference spectrum is the under-the-flightpath spectrum, at the radiation angle considered, corrected to the reference range of 100 m. This spectrum is used to estimate the under-the-flightpath spectrum at any sideline range using an appropriate value of atmospheric attenuation rate and the inverse-square law for range correction.

(e) Calculate the ground reflection spectrum for the sideline location and correct the measured spectrum to free-field conditions.

(f) From the reference spectrum calculate the under-the-flightpath free-field spectrum at the same propagation range as the sideline location considered.

(g) Subtract spectrum (e) from spectrum (f) to obtain the lateral attenuation in each one-third octave band.

Typical values of one-third octave band lateral attenuation are shown in Figure 2 plotted against aircraft elevation angle. Data from three aircraft, of similar type, having four underwing mounted turbojet engines are included in this figure. The effect of range has not been considered in the data plotted and this effect will account for some of the data spread.

The majority of flyover noise data are now analysed. On completion of this analysis the task of correlating these data against frequency, range and elevation angle will be addressed. From the correlation of these data a prediction procedure, suitable for use in noise contour estimation, will be developed.

## 4. REFERENCES

1. C.I. CHESSEL 1977, J. Acoust.Soc.Am. 62, 825-834. Noise propagation along an impedance boundary.

2. ESDU 1980, Item No. 80038. The correction of measured noise spectra for the effects of ground reflection.

3. ESDU 1981, Item No. 81035. An introduction to aircraft lateral noise attenuation.

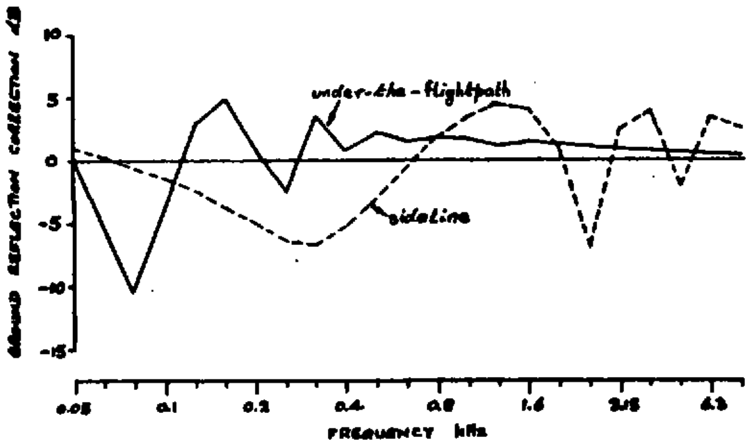


FIGURE 1. ⅓-OCTAVE BAND GROUND REFLECTION CORRECTION SPECTRA

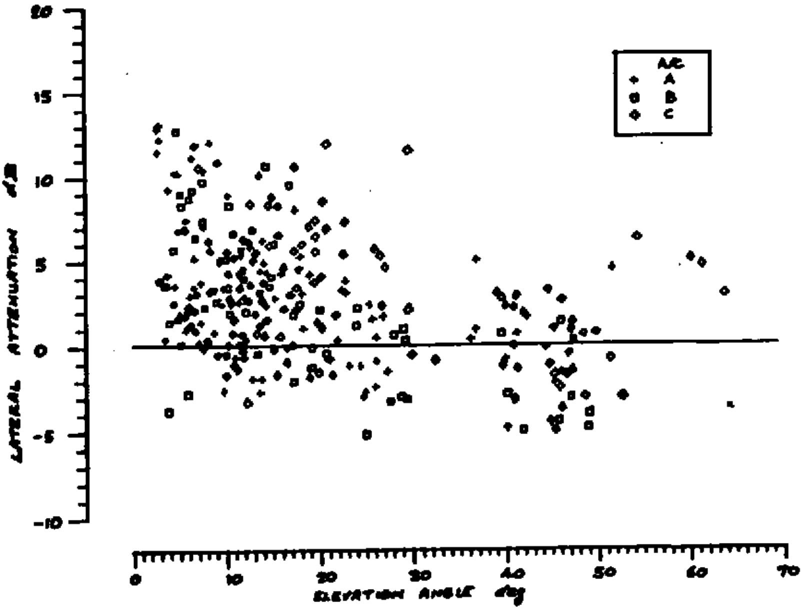


FIGURE 2. LATERAL ATTENUATION IN THE 1/3-OCTAVE BAND CENTRED AT 500 Hz