

AN INTRODUCTION TO AIRCRAFT NOISE LATERAL ATTENUATION

1. NOTATION

SI Units

A_L	lateral attenuation	dB
c	speed of sound	m/s
f	frequency	Hz
G	ground-reflection correction	dB
H	height	m
k	constant in Equation (3.1)	
L	far-field sound pressure level	dB
Ma	aircraft Mach number	
P	attenuation of sound pressure level due to spherical wave spreading and molecular absorption	dB
r	distance between aircraft and observer	m
α	angle of pitch (see Sketch 2.1)	deg
β	angle of elevation (see Sketch 2.1)	deg
θ	angle of radiation relative to aircraft/engine axis (see Sketch 2.1)	deg
θ'	angle of radiation relative to flight-path (see Sketch 2.1)	deg
ϕ	angle of ray from the vertical	deg

Subscripts

a	aircraft
b	background
f	free-field
m	measured
o	observer
s	sideline

Issued November 1981

sc	corrected sideline
u	under-the-flight-path
uc	corrected under-the-flight-path

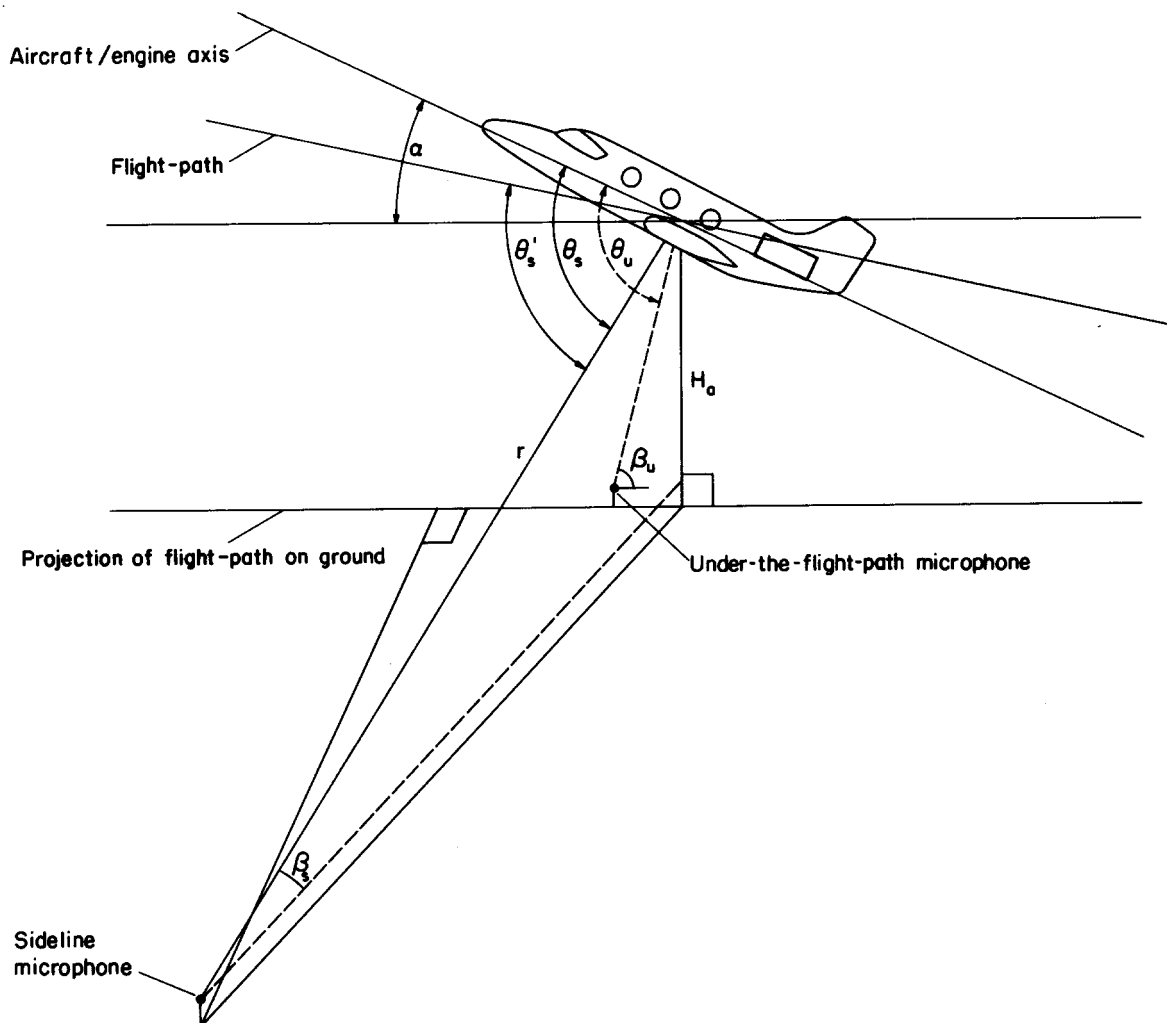
2. INTRODUCTION

The determination of noise levels on the ground due to aircraft in flight is of increasing importance as the ground noise level is used in both planning land use and controlling aircraft movements. An important component in the prediction of ground noise levels is the estimation of the attenuation of sound as it propagates close to the ground plane. This Item describes the analysis of aircraft flyover noise measurements to determine the lateral attenuation of sound and discusses the factors which may influence this attenuation.

Lateral attenuation, A_L , is defined as the difference between the under-the-flight-path 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, θ , and the same aircraft flight conditions (configuration, engine thrust setting, *etc.*). The free-field levels are obtained from the measured sound levels by removing the effect of ground reflections: a procedure for correcting measured data to free-field conditions is given in Item No. 80038.

This broad definition of lateral attenuation means that it includes any additional absorption of sound energy as it propagates over the ground surface not accounted for in the ground-reflection correction theory (often referred to as extra ground attenuation), and the effect of ground undulations. Also included are such diverse effects as (a) source installation effects, which can be broken down into airframe shielding, reflections and scattering from the airframe, and jet-by-jet shielding; (b) flow-field effects such as shielding due to vortices and wing flow-field effects; and (c) atmospheric effects such as refraction of the sound waves due to wind and temperature gradients and attenuation due to atmospheric turbulence.

Experimental evidence from carefully controlled tests in steady stable atmospheric conditions, with measurements being made over a nominally flat surface with no obstructions, suggest that lateral attenuation is a function of elevation angle, β , (see Sketch 2.1) and the range between the aircraft and the observer and furthermore may be frequency dependent.



Sketch 2.1 Aircraft – observer geometry

It appears that the principal components of lateral attenuation are extra ground attenuation, jet-by-jet shielding and installation effects.

3. ANALYSIS FOR LATERAL ATTENUATION

Assuming steady engine conditions and a fixed aircraft configuration (*i.e.* flap settings, undercarriage position, *etc.*) the noise radiated by the aircraft, L_a , is a function of the radiation angle, θ . The sound pressure level measured at the position of an observer, L_{om} , is given by

$$L_{om} = L_a + G - P - A_L - k \log_{10}(1 - Ma \cos \theta'), \quad (3.1)$$

where G is the ground-reflection correction, P is the attenuation due to spherical spreading (inverse square law) and molecular absorption assuming straight line propagation, and A_L is the lateral attenuation. The convective amplification term is given by $(k \log_{10}(1 - Ma \cos \theta'))$, where Ma is the aircraft Mach number and θ' the angle between the flightpath and the line from the aircraft to the observer, and k is dependent on the type of noise source and will be of the order of 40.

The free-field sound pressure level at the position of the observer, L_{of} , is given by

$$L_{of} = L_{om} - G. \quad (3.2)$$

Equation (3.1) applies to both sideline and under-the-flight-path measuring positions and hence subtracting the sideline level, L_s from the under-the-flight-path level, L_u for a given aircraft configuration and thrust condition yields

$$L_{ou} - L_{os} = L_{au} - L_{as} + (G_u - G_s) - (P_u - P_s) - (A_{Lu} - A_{Ls}) - k \log_{10} \left[\frac{(1 - Ma \cos \theta'_u)}{(1 - Ma \cos \theta'_s)} \right]. \quad (3.3)$$

After correcting for convective amplification, propagation effects and ground-reflection effects, Equation (3.3) can be written as

$$L_{uc} - L_{sc} = L_{au} - L_{as} + A_{Ls} - A_{Lu}. \quad (3.4)$$

The aircraft source term, L_a , has some dependence on atmospheric conditions, such as temperature, pressure and density. Thus in comparing two noise measurements it is necessary to ensure that the effect of the atmospheric conditions on the source are minimised. This can be done either by correcting the source level for the test conditions or by testing under constant atmospheric conditions. Assuming a constant source level, lateral attenuation is found by analysing the noise time-histories measured at sideline and under-the-flight-path at a constant radiation angle, $\theta_u = \theta_s = \theta$. As the radiation angles are the same, the source terms in Equation (3.4) will cancel and the lateral attenuation is given by the difference between the corrected levels.

$$A_{Ls} - A_{Lu} = L_{uc} - L_{sc}. \quad (3.5)$$

As the elevation angle of the aircraft at the time of emission of the under-the-flight-path spectrum is large, many of the components of lateral attenuation will be very small. Jet-by-jet shielding is small because sound from each engine propagates to the observer without passing through an adjacent jet efflux (see Section 3.4). Also the large elevation angle ensures that there is little overground sound propagation so that any attenuation associated with this propagation path is negligible; further the distortion of the propagation path due to wind and temperature gradients (see Section 3.2) is minimised.

Therefore referencing the lateral attenuation to the under-the-flight-path spectrum gives

$$A_L = L_{uc} - L_{sc}. \quad (3.6)$$

3.1 Ground-Reflection Correction Effects

For a detailed understanding of lateral attenuation, the large spectral distortions caused by ground-reflections must be removed from the data. In a one-third octave band spectrum, measured using a microphone mounted 1.2 m above the ground plane, significant distortions will occur in the frequency range of 50–1000 Hz. The particular frequencies at which these effects will occur in any given case depend on the ground surface, the range and the angle of elevation. Item No. 94035 gives advice on how these effects can be minimised in the measured data and also a recommended procedure for calculating the ground-reflection correction.

The analysis presented in Section 3 included a difference term ($G_u - G_s$) where G_u is the ground-reflection