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The prediction of sound attenuation as a result of propagation close to the ground

Associated software: ESDUpac A9436
ESDUpac B9436
VIEWpac M9436



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THE PREPARATION OF THIS DATA ITEM

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THE PREDICTION OF SOUND ATTENUATION AS A RESULT OF PROPAGATION CLOSE TO THE GROUND

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THE PREDICTION OF SOUND ATTENUATION AS A RESULT OF PROPAGATION CLOSE TO THE GROUND

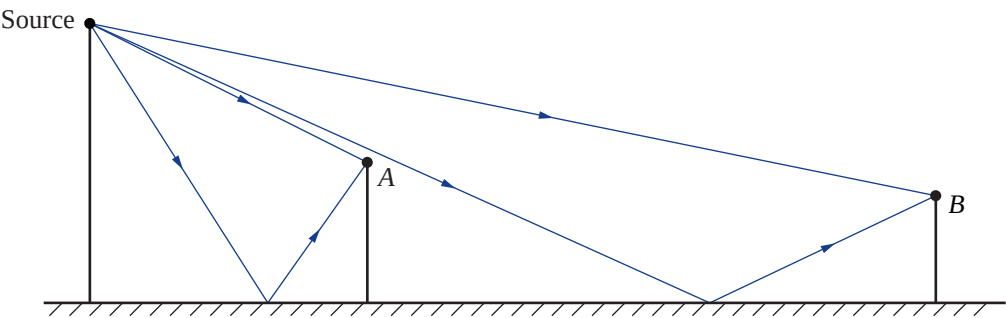
1. NOTATION

		<i>SI Units</i>
A_a	band averaged ground reflection correction	dB
A_d	discrete frequency ground reflection correction	dB
c	speed of sound	m/s
C_A	ground reflection correction at location A (see Sketch 2.1)	dB
C_B	ground reflection correction at location B (see Sketch 2.1)	dB
D	horizontal separation of source and microphone	m
$F(w)$	boundary loss factor	
F_A	free-field spectrum at location A (see Sketch 2.1)	dB
F_B	free-field spectrum at location B (see Sketch 2.1)	dB
f	frequency	Hz
L	turbulence scale parameter	m
M_A	measured spectrum at location A (see Sketch 2.1)	dB
M_B	measured spectrum at location B (see Sketch 2.1)	dB
P	parameter in Equation (4.4)	$m^{3/2}$
Q	relative image source strength	
r_1	pathlength of direct ray between source and receiver (see Sketch 3.1)	m
r_2	pathlength of reflected ray between source and receiver (see Sketch 3.1)	m
T	air temperature	K
w	numerical distance	
Z	normalised acoustic impedance	
α	inverse effective depth of porous surface layer	m^{-1}
β	parameter in Equation (4.3)	
Γ	mutual coherence function	
γ	ratio of specific heat capacities of air	
ζ	parameter in Equation (3.5)	

η	parameter in Equation (3.5)	
θ	phase angle of complex image source strength	rad
λ	wavelength	m
$\langle \mu^2 \rangle$	fluctuating index of refraction	
ρ	density of air	kg/m ³
σ_e	effective flow resistivity	kN s/m ⁴
σ_V	rms value of wind velocity fluctuation	m/s
σ_T	rms value of temperature fluctuation	K
ϕ	ground reflection angle (<i>i.e.</i> angle made by incident or reflected ray with ground (see Sketch 3.1)	rad
ω	angular frequency	rad/s

2. INTRODUCTION

This Item provides a computerized method for predicting the attenuation of sound as it propagates between two fixed locations in the presence of a stationary noise source close to the ground. If the noise spectrum at one location is known, the method allows the user to predict the noise spectrum at any other location. For example, with reference to Sketch 2.1, the method allows the user to predict the attenuation of sound between any two locations, A and B. If the noise spectrum at location A is known, it is then possible to predict the noise spectrum at location B.



Sketch 2.1

The method considers the attenuation of sound due to spherical spreading, atmospheric absorption and accounts for the effect of ground reflection and air turbulence. The method does not account for variations in sound velocity due to wind and temperature gradients. Over short ranges, wind and temperature gradient effects may be calculated rapidly using the method described in Reference 10. Over longer ranges the Fast Field Program in Reference 12 should be used.

The implementation of computer programs, known as ESDUpacs and VIEWpacs,* provided with this Item are described in Appendix A. The programs calculate the A-weighted sound pressure level, dBA, the overall sound pressure level, OASPL and the perceived noise level, PNL, when appropriate, of the spectra at locations A and B.

3. METHOD OF CALCULATION

The components of sound attenuation that this Item addresses are those due to:

- i) spherical spreading,
- ii) atmospheric absorption
- and iii) ground reflection with air turbulence effects.

The calculation of the first of these components is straightforward. For every doubling of distance from the noise source, the sound pressure level at the reception point drops by 6 dB.

The two other components are more difficult to calculate, and each of them is considered separately and in greater detail below. First, however, the basic method of calculating the sound attenuation between two points, for example A and B in Sketch 2.1, is described.

By definition, the difference between a measured spectrum at a point located above the ground and the free-field spectrum at that point is caused by ground reflection effects.

If, at location A, the measured spectrum is denoted by M_A , the free-field spectrum is denoted by F_A and the ground reflection correction denoted by C_A ,

$$\text{then} \quad M_A = F_A + C_A \quad (3.1)$$

$$\text{and similarly} \quad M_B = F_B + C_B. \quad (3.2)$$

Then, the attenuation between points A and B can be expressed as

$$M_A - M_B = F_A - F_B + C_A - C_B. \quad (3.3)$$

$F_A - F_B$ is the difference in free-field levels at locations A and B which can be attributed to spherical spreading and air absorption. $C_A - C_B$ can be calculated from separate calculations of the ground reflection correction at locations A and B.

If M_A is known, then it is simple to predict M_B once $M_A - M_B$ has been evaluated.

This Item offers a modular approach where the user can compute the attenuation arising from any combination of these three components.

The calculation of attenuation from air absorption and ground reflection effects is carried out here using derivations from established methods described in detail in ESDU 78003 (Reference 9) and ESDU 94035 (Reference 11) respectively.

* The full ESDUpac number has an appended V followed by two digits. These digits indicate the ESDUpac version number. For example, the full ESDUpac number for version 1.0 of ESDUpac A9436 is A9436V10. The version appendage will not be used when referring to ESDUpacs in the text of this Item. See Introduction to ESDUpacs for a full description of the ESDUpac numbering system. The current version of the ESDUpac is given in Appendix A and on the example program output in Section A.1.

This Item provides in one convenient package a means by which the major components of sound attenuation can be estimated together. Though full details of these methods are available in the two ESDU Items mentioned above, brief descriptions are provided here.

The sources from which the ESDU Items have been derived are given in Derivations 1 to 7.

3.1 Band Attenuation of Sound by Atmospheric Absorption

The atmospheric attenuation of sound over a frequency band is obtained by integrating discrete frequency attenuation values over the frequency range. These discrete frequency attenuation values are given in ESDU 78002 (Reference 8). If the noise spectrum for which attenuations are to be estimated is available, the spectrum slope is used to evaluate the band attenuation. If no spectrum is available then the band attenuation is calculated on the basis of assuming the spectrum to be that of white noise.

The method used in this Item is a modified version of that described in Reference 9.

3.2 Ground reflection effects

Ground reflection effects are due to interference between the direct wave between a noise source and a receiver and the wave that reaches the receiver after being reflected off the ground. The phase relationship between the two waves which causes this interference is determined by the difference in path lengths between the direct and reflected waves, and the impedance of the ground material. In addition, air turbulence affects the coherence between direct and reflected rays and modifies the ground reflection effect.

In the theory used to calculate the ground reflection effect, spherical waves are broken down into a large number of plane waves. The plane wave sound pressure reflection coefficient, which is dependent on the angle of incidence of the reflected wave and the ground impedance, can then be used. The prediction method also accounts for the effect of air turbulence.

The basic equations for calculating the ground reflection correction are given below. A more detailed derivation is given in Reference 11.

For a point source located above a semi-infinite boundary (see Sketch 3.1), the arithmetical difference between the sound pressure level measured in the presence of the boundary and the sound pressure level measured in free space, for a discrete frequency, is given by

$$A_d = 10 \log_{10} \left[1 + \left(\frac{r_1}{r_2} |Q| \right)^2 + 2 \left(\frac{r_1}{r_2} \right) \Gamma |Q| \cos \left\{ \frac{2\pi(r_2 - r_1)}{\lambda} + \theta \right\} \right]. \quad (3.4)$$