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# Acoustics — Attenuation of sound during propagation outdoors —

## Part 2:
General method of calculation

*Acoustique — Atténuation du son lors de sa propagation à l'air libre —*

*Partie 2: Méthode générale de calcul*

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9613-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors:*

— *Part 1: Calculation of the absorption of sound by the atmosphere*

— *Part 2: General method of calculation*

Part 1 is a detailed treatment restricted to the attenuation by atmospheric absorption processes. Part 2 is a more approximate and empirical treatment of a wider subject — the attenuation by all physical mechanisms.

Annexes A and B of this part of ISO 9613 are for information only.

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## Introduction

The ISO 1996 series of standards specifies methods for the description of noise outdoors in community environments. Other standards, on the other hand, specify methods for determining the sound power levels emitted by various noise sources, such as machinery and specified equipment (ISO 3740 series), or industrial plants (ISO 8297). This part of ISO 9613 is intended to bridge the gap between these two types of standard, to enable noise levels in the community to be predicted from sources of known sound emission. The method described in this part of ISO 9613 is general in the sense that it may be applied to a wide variety of noise sources, and covers most of the major mechanisms of attenuation. There are, however, constraints on its use, which arise principally from the description of environmental noise in the ISO 1996 series of standards.

# Acoustics — Attenuation of sound during propagation outdoors —

## Part 2:
General method of calculation

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## 1 Scope

This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in parts 1 to 3 of ISO 1996) under meteorological conditions favourable to propagation from sources of known sound emission.

These conditions are for downwind propagation, as specified in 5.4.3.3 of ISO 1996-2:1987 or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.

The method also predicts a long-term average A-weighted sound pressure level as specified in ISO 1996-1 and ISO 1996-2. The long-term average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions.

The method specified in this part of ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects:

— geometrical divergence;
— atmospheric absorption;
— ground effect;
— reflection from surfaces;
— screening by obstacles.

Additional information concerning propagation through housing, foliage and industrial sites is given in annex A.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. It does not apply to sound from aircraft in flight, or to blast waves from mining, military or similar operations.

To apply the method of this part of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

NOTE 1 If only A-weighted sound power levels of the sources are known, the attenuation terms for 500 Hz may be used to estimate the resulting attenuation.

The accuracy of the method and the limitations to its use in practice are described in clause 9.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

## 7.2 Atmospheric absorption ($A_{atm}$)

The attenuation due to atmospheric absorption $A_{atm}$, in decibels, during propagation through a distance $d$, in metres, is given by equation (8):

$$A_{atm} = \alpha d / 1\,000 \qquad \ldots (8)$$

where $\alpha$ is the atmospheric attenuation coefficient, in decibels per kilometre, for each octave band at the midband frequency (see table 2).

For values of $a$ at atmospheric conditions not covered in table 2, see ISO 9613-1.

NOTES

8 The atmospheric attenuation coefficient depends strongly on the frequency of the sound, the ambient temperature and relative humidity of the air, but only weakly on the ambient pressure.

9 For calculation of environmental noise levels, the atmospheric attenuation coefficient should be based on average values determined by the range of ambient weather which is relevant to the locality.

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## 7.3 Ground effect ($A_{gr}$)

### 7.3.1 General method of calculation

Ground attenuation, $A_{gr}$, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver. The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified (see figure 1):

a) the source region, stretching over a distance from the source towards the receiver of $30h_s$, with a maximum distance of $d_p$ ($h_s$ is the source height, and $d_p$ the distance from source to receiver, as projected on the ground plane);

b) the receiver region, stretching over a distance from the receiver back towards the source of $30h_r$, with a maximum distance of $d_p$ ($h_r$ is the receiver height);

c) a middle region, stretching over the distance between the source and receiver regions. If $d_p < (30h_s + 30h_r)$, the source and receiver regions will overlap, and there is no middle region.

According to this scheme, the ground attenuation does not increase with the size of the middle region, but is mostly dependent on the properties of source and receiver regions.

The acoustical properties of each ground region are taken into account through a ground factor $G$. Three categories of reflecting surface are specified as follows.

**Table 2 — Atmospheric attenuation coefficient $\alpha$ for octave bands of noise**

| **Temperature** | **Relative humidity** | **Atmospheric attenuation coefficient $\alpha$, dB/km** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Nominal midband frequency, Hz** | | | | | | | |
| °C | % | 63 | 125 | 250 | 500 | 1 000 | 2 000 | 4 000 | 8 000 |
| 10 | 70 | 0,1 | 0,4 | 1,0 | 1,9 | 3,7 | 9,7 | 32,8 | 117 |
| 20 | 70 | 0,1 | 0,3 | 1,1 | 2,8 | 5,0 | 9,0 | 22,9 | 76,6 |
| 30 | 70 | 0,1 | 0,3 | 1,0 | 3,1 | 7,4 | 12,7 | 23,1 | 59,3 |
| 15 | 20 | 0,3 | 0,6 | 1,2 | 2,7 | 8,2 | 28,2 | 88,8 | 202 |
| 15 | 50 | 0,1 | 0,5 | 1,2 | 2,2 | 4,2 | 10,8 | 36,2 | 129 |
| 15 | 80 | 0,1 | 0,3 | 1,1 | 2,4 | 4,1 | 8,3 | 23,7 | 82,8 |

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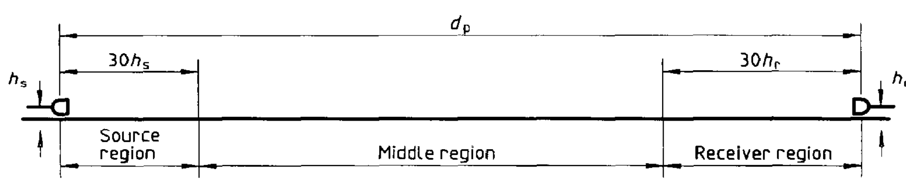


**Figure 1 — Three distinct regions for determination of ground attenuation**

a) **Hard ground,** which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground $G = 0$.

NOTE 10 It should be recalled that inversion conditions over water are not covered by this part of ISO 9613.

b) **Porous ground,** which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground $G = 1$.

c) **Mixed ground:** if the surface consists of both hard and porous ground, then $G$ takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations $A_s$ for the source region specified by the ground factor $G_s$ (for that region), $A_r$ for the receiver region specified by the ground factor $G_r$, and $A_m$ for the middle region specified by the ground factor $G_m$, using the expressions in table 3. (Alternatively, the functions $a'$, $b'$, $c'$ and $d'$ in table 3 may be obtained directly from the curves in figure 2.) The total ground attenuation for that octave band shall be obtained from equation (9):

$$A_{gr} = A_s + A_r + A_m \qquad \ldots (9)$$

NOTE 11 In regions with buildings, the influence of the ground on sound propagation may be changed (see A.3).

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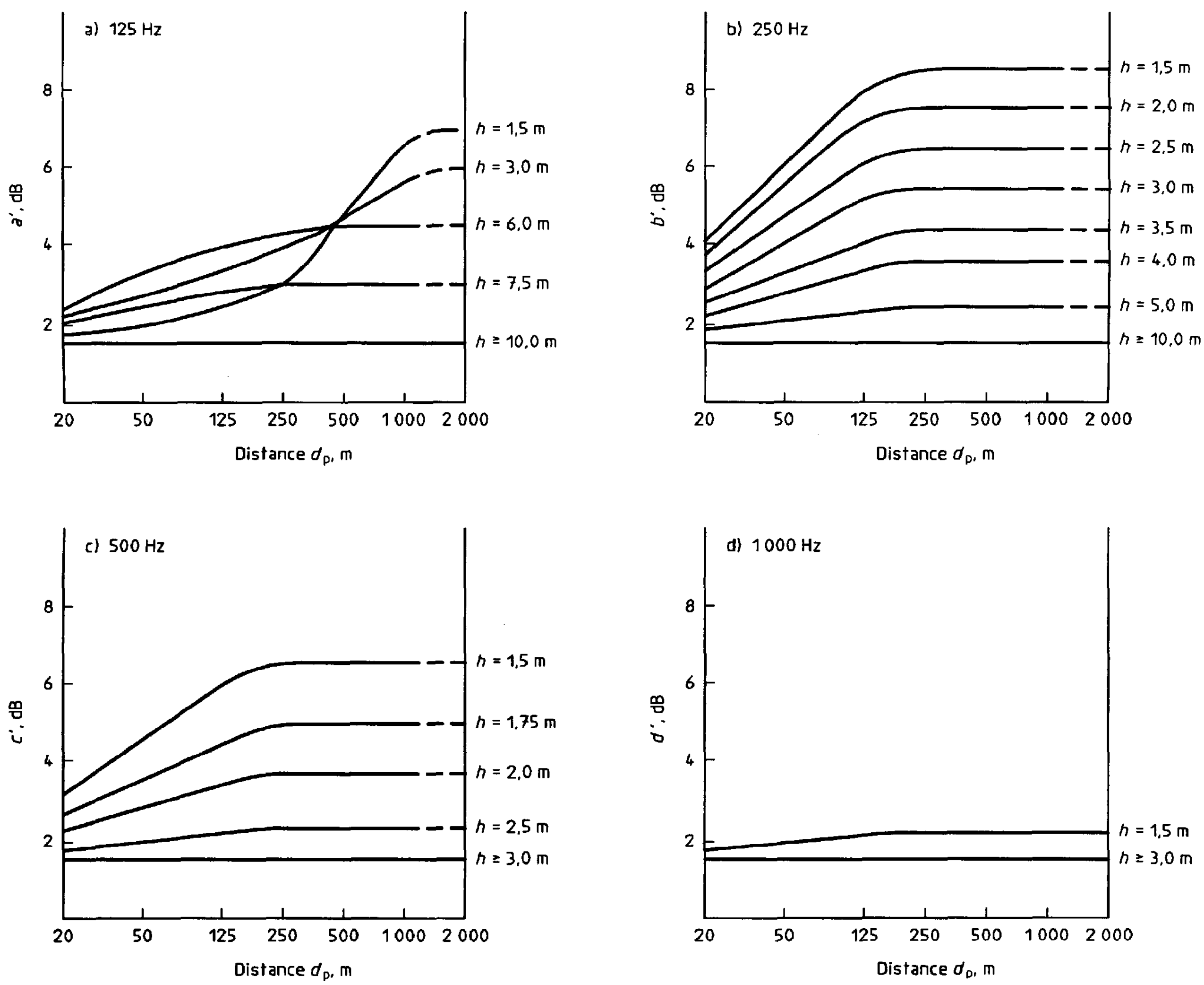


**Figure 2 — Functions $a'$, $b'$, $c'$ and $d'$ representing the influence of the source-to-receiver distance $d_p$ and the source or receiver height $h$, respectively, on the ground attenuation $A_{gr}$** (computed from equations in table 3)

The use of equations (1) to (5) and (7) to (20) (and therefore also table 5) is limited to case a): meteorological conditions only. Case b) is relevant only to the use of equations (6), (21) and (22). There are also a substantial number of limitations (non-meteorological) in the use of individual equations. Equation (9) is, for example, limited to approximately flat terrain. These specific limitations are described in the text accompanying the relevant equation.

**Table 5 — Estimated accuracy for broadband noise of $L_{AT}$(DW) calculated using equations (1) to (10)**

| **Height, $h$ *)** | **Distance, $d$ *)** | |
|---|---|---|
| | $0 < d < 100$ m | $100 \text{ m} < d < 1\,000$ m |
| $0 < h < 5$ m | ± 3 dB | ± 3 dB |
| $5 \text{ m} < h < 30$ m | ± 1 dB | ± 3 dB |

*) $h$ is the mean height of the source and receiver.
$d$ is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

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