INTERNATIONAL STANDARD

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Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane

Acoustique — Détermination des niveaux de puissance et d'énergie acoustiques émis par les sources de bruit à partir de la pression acoustique — Méthodes d'expertise pour des conditions approchant celles du champ libre sur plan réfléchissant

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Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 3744:2010
https://standards.iteh.ai/catalog/standards/sist/a355d43f-0d3e-4d1e-8c07-
dd257783f6c6/iso-3744-2010

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3744 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition of ISO 3744 cancels and replaces the second edition (ISO 3744:1994) and ISO 4872:1978, of which it constitutes a merger and a technical revision.

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Introduction

This International Standard is one of the series ISO 3741[2] to ISO 3747[6], which specify various methods for determining the sound power levels and sound energy levels of noise sources including machinery, equipment and their sub-assemblies. General guidelines to assist in the selection are provided in ISO 3740[1]. The selection depends on the environment of the available test facility and on the precision of the sound power level or sound energy level values required. It may be necessary to establish a noise test code (see ISO 12001) for the individual noise source in order to select the appropriate sound measurement surface and microphone array from among those allowed in each member of the ISO 3741[2] to ISO 3747[6] series, and to give requirements on test unit mounting, loading and operating conditions under which the sound power levels or sound energy levels are to be obtained. The sound power emitted by a given source into the test environment is calculated from the mean square sound pressure that is measured over a hypothetical measurement surface enclosing the source, and the area of that surface. The sound energy for a single sound event is calculated from this sound power and the time over which it existed.

The methods specified in this International Standard permit the determination of the sound power level and the sound energy level in frequency bands optionally with frequency A-weighting applied.

For applications where greater accuracy is required, reference can be made to ISO 3745, ISO 3741[2] or ISO 9614[13]-[15]. If the relevant criteria for the measurement environment specified in this International Standard are not met, it might be possible to refer to another standard from this series, or to ISO 9614[13]-[15].

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This International Standard describes methods of accuracy grade 2 (engineering grade) as defined in ISO 12001, when the measurements are performed in a space that approximates an acoustically free field over a reflecting plane. Such an environment can be found in a specially designed room, or within industrial buildings or outdoors. Ideally, the test source should be mounted on a sound-reflecting plane located in a large open space. For sources normally installed on the floor of machine rooms, corrections are defined to account for undesired reflections from nearby objects, walls and the ceiling, and for the residual background noises that occur there.

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Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane

1 Scope

1.1 General

This International Standard specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping the noise source (machinery or equipment) in an environment that approximates to an acoustic free field near one or more reflecting planes. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands or with A-weighting applied, is calculated using those measurements.

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NOTE Differently shaped measurement surfaces can yield differing estimates of the sound power level of a given noise source and an appropriately drafted noise test code (see ISO 12001) gives detailed information on the selection of the surface.

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1.2 Types of noise and noise sources

The methods specified in this International Standard are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

This International Standard is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or sub-assembly), provided the conditions for the measurements can be met.

NOTE It is possible that the conditions for measurements given in this International Standard are impracticable for very tall or very long sources such as chimneys, ducts, conveyors and multi-source industrial plants. A noise test code for the determination of noise emission of specific sources can provide alternative methods in such cases.

1.3 Test environment

The test environments that are applicable for measurements made in accordance with this International Standard can be located indoors or outdoors, with one or more sound-reflecting planes present on or near which the noise source under test is mounted. The ideal environment is a completely open space with no bounding or reflecting surfaces other than the reflecting plane(s) (such as that provided by a qualified hemi-anechoic chamber), but procedures are given for applying corrections (within limits that are specified) in the case of environments that are less than ideal.

1.4 Measurement uncertainty

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with this International Standard, for measurements made in limited bands of frequency and with frequency A-weighting applied. The uncertainty conforms to ISO 12001:1996, accuracy grade 2 (engineering grade).

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 3745, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic test rooms and hemi- anechoic test rooms*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources for the determination of sound power levels*

ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

ISO/IEC Guide 98-3, *Uncertainty in measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

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IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

ISO 3744:2010
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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
sound pressure
p
difference between instantaneous pressure and static pressure

NOTE 1 Adapted from ISO 80000-8:2007[21], 8-9.2.

NOTE 2 Sound pressure is expressed in pascals.

3.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to the square of a reference value, p_0, expressed in decibels

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB} \quad (1)$$

where the reference value, p_0, is 20 µPa

[ISO/TR 25417:2007[20], 2.2]

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NOTE 1 If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{pA} denotes the A-weighted sound pressure level.

NOTE 2 This definition is technically in accordance with ISO 80000-8:2007[21], 8-22.

3.3
time-averaged sound pressure level
$L_{p,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the sound pressure, p, during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0, expressed in decibels

$$L_{p,T} = 10 \lg \left[\frac{\frac{1}{T} \int_{t_1}^{t_2} p^2(t) \mathrm{d}t}{p_0^2} \right] \mathrm{dB} \tag{2}$$

where the reference value, p_0, is 20 µPa

NOTE 1 In general, the subscript "T" is omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

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NOTE 2 Time-averaged sound pressure levels are often A-weighted, in which case they are denoted by $L_{pA,T}$, which is usually abbreviated to L_{pA}.

NOTE 3 Adapted from ISO/TR 25417:2007[20], 2.3.

ISO 3744:2010
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1d0b57898fcd/iso-3744-2010

3.4
single event time-integrated sound pressure level
L_E
ten times the logarithm to the base 10 of the ratio of the integral of the square of the sound pressure, p, of an isolated single sound event (burst of sound or transient sound) over a stated time interval T (starting at t_1 and ending at t_2), to a reference value, E_0, expressed in decibels

$$L_E = 10 \lg \left[\frac{\int_{t_1}^{t_2} p^2(t) \mathrm{d}t}{E_0} \right] \mathrm{dB} \tag{3}$$

where the reference value, E_0, is $(20\ \mu\text{Pa})^2\ \text{s} = 4 \times 10^{-10}\ \text{Pa}^2\ \text{s}$

NOTE 1 This quantity can be obtained by $L_{p,T} + 10 \lg \left[\frac{T}{T_0} \right] \mathrm{dB}$, where T_0 = 1 s.

NOTE 2 When used to measure sound immission, this quantity is usually called "sound exposure level" (see ISO/TR 25417:2007[20]).

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3.5
measurement time interval
T
portion or a multiple of an operational period or operational cycle of the noise source under test for which the time-averaged sound pressure level is determined

NOTE Measurement time interval is expressed in seconds.

3.6
acoustic free field
sound field in a homogeneous, isotropic medium free of boundaries

NOTE In practice, an acoustic free field is a field in which the influence of reflections at the boundaries or other disturbing objects is negligible over the frequency range of interest.

3.7
acoustic free field over a reflecting plane
acoustic free field in the half-space above an infinite reflecting plane in the absence of any other obstacles

3.8
reflecting plane
sound reflecting planar surface on which the noise source under test is located

3.9
frequency range of interest
for general purposes, the frequency range of octave bands with nominal mid-band frequencies from 125 Hz to 8 000 Hz (including one-third octave bands with mid-band frequencies from 100 Hz to 10 000 Hz)

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NOTE For special purposes, the frequency range can be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified frequency range. Changes to the frequency range of interest are included in the test report.

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3.10
reference box
hypothetical right parallelepiped terminating on the reflecting plane(s) on which the noise source under test is located, that just encloses the source including all the significant sound radiating components and any test table on which the source is mounted

NOTE If required, the smallest possible test table can be used for compatibility with emission sound pressure measurements at bystander positions in accordance with, for example, ISO 11201[18].

3.11
characteristic source dimension
d_O
distance from the origin of the co-ordinate system to the farthest corner of the reference box

NOTE Characteristic source dimension is expressed in metres.

3.12
measurement distance
d
distance from the reference box to a parallelepiped measurement surface

NOTE Measurement distance is expressed in metres.

3.13
measurement radius
r
radius of a hemispherical, half-hemispherical or quarter-hemispherical measurement surface

NOTE Measurement radius is expressed in metres.

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3.14
measurement surface
hypothetical surface of area, S, on which the microphone positions are located at which the sound pressure levels are measured, enveloping the noise source under test and terminating on the reflecting plane(s) on which the source is located

3.15
background noise
noise from all sources other than the noise source under test

NOTE Background noise includes contributions from airborne sound, noise from structure-borne vibration, and electrical noise in the instrumentation.

3.16
background noise correction
K_1
correction applied to the mean (energy average) of the time-averaged sound pressure levels over all the microphone positions on the measurement surface, to account for the influence of background noise

NOTE 1 Background noise correction is expressed in decibels.

NOTE 2 The background noise correction is frequency dependent; the correction in the case of a frequency band is denoted K_{1f}, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted K_{1A}.

3.17
environmental correction
K_2
correction applied to the mean (energy average) of the time-averaged sound pressure levels over all the microphone positions on the measurement surface, to account for the influence of reflected or absorbed sound

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ISO 3744:2010
https://standards.iteh.ai/catalog/standards/sist/a355d43f-0d3e-4d1e-8c07-dd9b77891bcb/iso-3744-2010

NOTE 1 Environmental correction is expressed in decibels.

NOTE 2 The environmental correction is frequency dependent; the correction in the case of a frequency band is denoted K_{2f}, where f denotes the relevant mid-band frequency, and that in the case of A-weighting is denoted K_{2A}.

NOTE 3 In general, the environmental correction depends on the area of the measurement surface and usually K_2 increases with S.

3.18
surface time-averaged sound pressure level
$\overline{L_p}$
mean (energy average) of the time-averaged sound pressure levels over all the microphone positions, or traverses, on the measurement surface, with the background noise correction, K_1, and the environmental correction, K_2, applied

NOTE Surface time-averaged sound pressure level is expressed in decibels.

3.19
surface single event time-integrated sound pressure level
$\overline{L_E}$
mean (energy average) of the single event time-integrated sound pressure levels at all the microphone positions, or traverses, on the measurement surface, with the background noise correction, K_1, and the environmental correction, K_2, applied

NOTE Surface single event time-integrated sound pressure level is expressed in decibels.

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3.20
sound power
P
through a surface, product of the sound pressure, p, and the component of the particle velocity, u_n, at a point on the surface in the direction normal to the surface, integrated over that surface

[ISO 80000-8:2007[21], 8-16]

NOTE 1 Sound power is expressed in watts.

NOTE 2 The quantity relates to the rate per time at which airborne sound energy is radiated by a source.

3.21
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power of a source, P, to a reference value, P_0, expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \text{ dB} \tag{4}$$

where the reference value, P_0, is 1 pW

NOTE 1 If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{WA} denotes the A-weighted sound power level.

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NOTE 2 This definition is technically in accordance with ISO 80000-8:2007[21], 8-23.

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[ISO/TR 25417:2007[20], 2.9]

ISO 3744:2010
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3.22
sound energy
J
integral of the sound power, P, over a stated time interval of duration T (starting at t_1 and ending at t_2)

$$J = \int_{t_1}^{t_2} P(t) \, dt \tag{5}$$

NOTE 1 Sound energy is expressed in joules.

NOTE 2 The quantity is particularly relevant for non-stationary, intermittent sound events.

[ISO/TR 25417:2007[20], 2.10]

3.23
sound energy level
L_J
ten times the logarithm to the base 10 of the ratio of the sound energy, J, to a reference value, J_0, expressed in decibels

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \tag{6}$$

where the reference value, J_0, is 1 pJ

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NOTE If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{JA} denotes the A-weighted sound energy level.

[ISO/TR 25417:2007[20], 2.11]

3.24
apparent directivity index
$D_{\mathrm{I}i}^{*}$
measure of the extent to which a noise source under test radiates sound in the direction of the ith microphone position on a measurement surface, relative to the mean sound radiation over the measurement surface

$$D_{\mathrm{I}i}^{*} = L_{pi(\mathrm{ST})} - \left[\overline{L'_{p(\mathrm{ST})}} - K_1 \right] \tag{7}$$

where

$L_{pi(\mathrm{ST})}$ is the background noise-corrected time-averaged (or single event time-integrated) sound pressure level for the ith microphone position on the measurement surface, with the noise source under test (ST) in operation, in decibels;

$\overline{L'_{p(\mathrm{ST})}}$ is the mean (energy average) time-averaged (or single event time-integrated) sound pressure level over all the microphone positions on the measurement surface for the noise source under test, in decibels;

K_1 is the background noise correction, in decibels.

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NOTE 1 Apparent directivity index is expressed in decibels.

NOTE 2 The apparent directivity index is determined using measured sound pressure levels from the noise source under test corrected for background noise, but with no corrections for the influence of the acoustic environment.

ISO 3744:2010
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3.25
apparent surface sound pressure level non-uniformity index
V_{I}^{*}
measure of the variability of measured sound pressure levels over the measurement surface

$$V_{\mathrm{I}}^{*} = \sqrt{\frac{1}{N_{\mathrm{M}} - 1} \sum_{i=1}^{N_{\mathrm{M}}} \left[L_{pi(\mathrm{ST})} - L_{p\mathrm{av}} \right]^2} \tag{8}$$

where

$L_{pi(\mathrm{ST})}$ is the background noise-corrected time-averaged (or single event time-integrated) sound pressure level for the ith microphone position on the measurement surface, with the noise source under test (ST) in operation, in decibels;

$L_{p\mathrm{av}}$ is the arithmetic average of the background noise-corrected time-averaged (or single event time-integrated) sound pressure levels over all the microphone positions on the measurement surface for the noise source under test, in decibels;

N_{M} is the number of microphone positions.

NOTE 1 Apparent surface sound pressure level non-uniformity index is expressed in decibels.

NOTE 2 When V_{I}^{*} is determined over the specific measurement surface given by the measurement radius, r, or measurement distance, d, the value is denoted $V_{\mathrm{I}r}^{*}$ or $V_{\mathrm{I}d}^{*}$, respectively.

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NOTE 3 The apparent surface sound pressure level non-uniformity index is determined using measured sound pressure levels from the noise source under test, corrected for background noise, but with no corrections for the influence of the acoustic environment.

4 Test environment

4.1 General

The test environments that are applicable for measurements in accordance with this International Standard are:

a) a laboratory room or a flat outdoor area which is adequately isolated from background noise (see 4.2) and which provides an acoustic free field over a reflecting plane;

b) a room or a flat outdoor area which is adequately isolated from background noise (see 4.2) and in which an environmental correction can be applied to allow for a limited contribution from the reverberant field to the sound pressures on the measurement surface.

Environmental conditions having an adverse effect on the microphones used for the measurements (e.g. strong electric or magnetic fields, wind, impingement of air discharge from the noise source being tested, high or low temperatures) shall be avoided. The instructions of the manufacturer of the measuring instrumentation regarding adverse environmental conditions shall be followed.

In an outdoor area, care shall be taken to minimize the effects of adverse meteorological conditions (e.g. temperature, humidity, wind, precipitation) on the sound propagation and on sound generation over the frequency range of interest or on the background noise during the course of the measurements.

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When a reflecting surface is not a ground plane or is not an integral part of a test room surface, particular care should be exercised to ensure that the plane does not radiate any appreciable sound due to vibrations.

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4.2 Criteria for background noise

4.2.1 Relative criteria

4.2.1.1 General

The time-averaged sound pressure level of the background noise measured and averaged (see 8.2.2) over the microphone positions, or traverses, on the measurement surface, shall be at least 6 dB, and preferably more than 15 dB, below the corresponding uncorrected time-averaged sound pressure level of the noise source under test when measured in the presence of this background noise. For measurements in frequency bands, this requirement shall be met in each frequency band within the frequency range of interest.

If this requirement is met, the background noise criteria of this International Standard are satisfied.

NOTE 1 A similar criterion is applied to single event sound pressure levels: the measurement time interval for the time average is the same as the measurement time interval associated with the single event.

NOTE 2 The noise associated with the microphone traversing mechanism, if one is used for the measurements, is considered to be part of the background noise. In such cases, the background noise is measured with the traversing mechanism operating.

4.2.1.2 Frequency band measurements

The requirements of 4.2.1.1 may not be achievable in all frequency bands, even when the background noise levels in the test room are extremely low and well controlled. Therefore, any band within the frequency range of interest in which the A-weighted sound power level or sound energy level of the noise source under test is at least 15 dB below the highest A-weighted band sound power level may be excluded from the frequency range of interest for the purposes of determining compliance with the criteria for background noise.

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4.2.1.3 A-weighted measurements

If the A-weighted sound power level or sound energy level is to be determined from frequency band levels and reported, the following steps shall be followed to determine whether this quantity meets the background noise criteria of this International Standard:

a) the A-weighted sound power level or sound energy level is computed in accordance with the procedures in this International Standard using the data from every frequency band within the frequency range of interest;

b) the computation is repeated, but excluding those bands for which $\Delta L_p < 6$ dB.

If the difference between these two levels is less than 0,5 dB, the A-weighted sound power level or sound energy level determined from the data for all bands may be considered as conforming to the background noise criteria of this International Standard.

NOTE If it is necessary to make measurements where the difference between the sound pressure levels of the background noise and the source together with the background noise is less than 6 dB, ISO 9614-1[13] or ISO 9614-2[14] can be used to give results of accuracy grade 2.

4.2.2 Absolute criteria

If it can be demonstrated that the background noise levels in the test room at the time of the measurements are less than or equal to those given in Table 1 for all bands within the frequency range of interest, the measurements can be taken as having met the background noise requirements of this International Standard, even if the 6 dB requirement (see 4.2.1.1) is not met for all bands. It can be assumed that the source emits little or no measurable noise in these frequency bands, and that the data reported represent an upper bound to the sound power level in these bands.

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In the case where some of the measured (either time-averaged or single event time-integrated) levels from the source under test are less than or equal to those given in Table 1, the frequency range of interest may be restricted to a contiguous range of frequencies that includes both the lowest and highest frequencies at which the sound pressure level from the noise source exceeds the corresponding value in Table 1. In such cases, the applicable frequency range of interest shall be reported.

4.2.3 Statement of non-conformity with criteria

If neither the relative criteria of 4.2.1 nor the absolute criteria in 4.2.2 are met, the report shall clearly state that the background noise requirements of this International Standard have not been met, and, in the case of frequency band measurements, shall identify the particular frequency bands that do not meet the criteria. Furthermore, the report shall not state or imply that the measurements have been made “in full conformity” with this International Standard.

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