Standard ECMA-108

6th Edition / December 2016

Determination of High-frequency Sound Power Levels Emitted by Information Technology and Telecommunications Equipment

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Introduction

In September 1981 Ecma International issued Standard ECMA-74 for the Measurement of Airborne Noise Emitted by Computer and Business Equipment. This Standard was contributed to ISO/TC 43; it formed the basis for International Standard ISO 7779. ECMA-74 and ISO 7779 are newly revised and have expanded scope to cover all information technology and telecommunications equipment.

This Standard ECMA-108 specifies methods for the determination of the sound power levels in the frequency range covered by the octave band centred at 16 kHz.

Some information and telecommunications equipment emits high-frequency noise which may be broad-band noise (e.g. paper noise of high-speed printing) or narrow-band noise and discrete tones (e.g. noise of switching power supplies and video display units). The measured levels are not frequency-weighted. The principal objective of this Standard is to prescribe methods for measuring the levels and frequencies of tones which are contained within the 16 kHz octave band.

The first edition of this Ecma Standard was published in December 1986. It has been adopted by ISO under the fast-track procedure as International Standard ISO 9295. The text of the second edition of Standard ECMA-108 has been adapted to the final wording of ISO 9295:1988. The text of the third edition of this Standard has been adapted to eliminate ambiguity in the determination of the A-weighted sound power levels of sounds that contain contributions in the octave band centred at 16 kHz, and to align with the fourth edition of ECMA-74 (1996). Like ECMA-74, the scope of ECMA-108 now covers all information technology and telecommunications equipment.

The fourth edition of this Ecma Standard was published in December 2008. The primary change is to incorporate changes in the tenth edition of ECMA-74, which limits the frequency range of interest for determining A-weighted sound power levels to one-third-octave bands with centre frequencies from 100 Hz to 10 000 Hz. With the fourth edition of ECMA-108, noise in the 16 kHz octave band is no longer used to determine overall A-weighted sound power level of the unit under test; only contributions in the 100 Hz – 10 000 Hz one-third-octave bands determined in accordance with the tenth edition of ECMA-74 are used to determine A-weighted sound power level.

The fifth edition of this Ecma Standard was published in December 2010. The primary change was to expand Table 1 – Values of the air absorption coefficient to include a wider temperature range. Also the equations to calculate the air absorption coefficient were aligned with ISO 9613-1.

The sixth edition of this Ecma Standard was published in December 2015. The primary change was to add clauses on measurement uncertainty (Clause 9) and determination of the sound power level under reference meteorological conditions (Clause 10). New references were added to ISO 3741, ISO 3744 and ISO/IEC Guide 98-3. The mean value $\overline{L_p}$, of N measurements of the time-averaged sound pressure level, which is based on recent updates of ISO 3741 and ISO 3744, is used.

The fifth edition of this Ecma Standard was the basis for ISO 9295:2015, which now applies to all type of machinery and equipment.

The sixth edition of this Ecma Standard incorporates other changes in ISO 9295:2015.

This Ecma Standard was developed by Technical Committee 26 and was adopted by the General Assembly of December 2016.

Determination of High-frequency Sound Power Levels Emitted by Information Technology and Telecommunications Equipment

1 Scope

This Standard ECMA-108 specifies four methods for the determination of the sound power levels of high-frequency noise emitted by information technology and telecommunications equipment in the frequency range covered by the octave band centred at 16 kHz, which includes frequencies between 11,2 kHz and 22,4 kHz. They are complementary to the methods described in Standard ECMA-74, ISO 3741 and ISO 3744. The first three methods are based on the reverberation test room technique. The fourth method makes use of a free field over a reflecting plane.

The test conditions which prescribe the installation and operation of the equipment are those specified in ECMA-74.

2 Conformance

A method for the measurement of high-frequency noise is in conformance with this Standard if it satisfies all the mandatory requirements of one of the four methods described herein specified in Clauses 6 to 9, and if the information recorded and reported is as specified in Clauses 12 and 13, respectively.

3 Normative references

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

ECMA-74, *Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment*

ISO 3741, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

ISO 3744, *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*

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

ISO 9613-1, *Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere*

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

4 Terms and definitions

For the purposes of this document, the terms and definitions given in ECMA-74, ISO 3741, and ISO 3744 apply.

5 Requirements for measurements in a reverberation test room

5.1 General

This Standard describes three methods using the reverberation test room techniques of ISO 3741. The first and the second method are usually called "direct methods" because they use directly measured or calculated reverberation times. The third method is the “comparison method”, in which a calibrated reference sound source is used from which the sound power levels of the equipment are determined by comparison.

All three methods require a determination of the mean time-averaged sound pressure level in the reverberant field.

As instrumentation and basic measurement techniques are the same for all three methods, they are summarized in 5.2 to 5.7. Additional requirements specific to each method are given separately. For additional information on instrumentation, see ISO 3741.

5.2 Meteorological conditions

The air absorption in the reverberation test room varies with temperature and humidity, particularly at frequencies above 1 000 Hz. The temperature θ in degrees Celsius (°C) and the relative humidity h_r, expressed as a percentage, shall be controlled during the sound pressure level measurements.

The product, $h_r \times (\theta + 5\ °C)$, shall not vary by more than ± 10 % during the measurements.

For equipment whose noise emissions intentionally vary with ambient temperature (e.g., by varying the speeds of air moving devices), the room temperature during the sound pressure level measurement shall be 23 °C ± 2 °C or, if the room temperature is outside these limits, then the fan shall be adjusted to the speed for an ambient temperature of 23 °C ± 2 °C.

The following conditions are recommended:

- Static pressure : 86 kPa to 106 kPa
- Temperature : 15 °C to 30 °C
- Relative humidity : 40% to 70 %

NOTE As indicated in Tables 1 and 2 for the temperature range of 18 °C to 27 °C, higher temperatures and higher humidity will tend to minimize the effects of atmospheric absorption.

5.3 Instrumentation

The sound measuring system, including the microphone, should have a flat frequency response for random incident sound in the 16 kHz octave band. The microphone response shall be corrected to give a flat frequency response within the 16 kHz octave band. The tolerances after correction shall be within ±1,0 dB in the frequency range of 11,2 kHz to 22,4 kHz.

NOTE 1 To meet this requirement a microphone with an outer diameter of 13,2 mm or less is usually required.

When the noise of the equipment under test is broad-band in character without any significant discrete tone, an analyser with a bandwidth of one-third-octave or less shall be used. When the noise of the equipment under test contains discrete frequencies, a narrow-band analyser which provides bandwidths of less than one-third-octave in width shall be used to determine the frequency of the tone(s).

NOTE 2 For narrow-band analysis, an analyser with a bandwidth equal to, or less than, one twelfth octave is appropriate. Digital analysers using fast Fourier transform (FFT) or equivalent techniques can be useful, particularly when the analyser combines narrow-band analysis and averaging.

5.4 Installation and orientation of microphone

The microphone shall be mounted at the end of a rotating boom traversing a circle with a diameter of at least 2 m. In order to reduce the influence of the direct field on the measured sound pressure level, the microphone shall be mounted pointing in such a way that the normal to its diaphragm is parallel to the axis of rotation and the microphone faces away from the equipment under test. The period of rotation shall be as required by ISO 3741.

Longer paths and traversing periods than the minimum values can be used to reduce the background noise of the drive mechanism, and to minimize modulation of any discrete tone(s) due to the moving microphone.

Care shall be taken to ensure that there is no electrical pick-up by the measurement instrumentation which can interfere with the sound pressure level measurement.

NOTE A test with a dummy microphone, and with the equipment under test in operation, can determine the electrical background level. Alternatively, if no dummy microphone is available without moving the microphone from the measurement position, this influence can be determined by sealing the microphone and pressure equalization vent in an electrical non-conductive enclosure providing an acoustical attenuation of at least 10 dB at all frequencies of interest.

5.5 Installation and orientation of equipment

Equipment shall be placed on the floor of the reverberation test room, at least 1 m from any wall, and at least 1,8 m from the point of closest approach of the microphone.

Four orientations of the equipment shall be used as follows.

– Operator side facing the centre of the microphone path.

– Equipment turned clockwise by 90° from its initial position about a vertical axis through its centre.

– Equipment turned clockwise by 180° from its initial position about a vertical axis through its centre.

– Equipment turned clockwise by 270° from its initial position about a vertical axis through its centre.

Alternatively, equipment shall be placed on a turntable, and the turntable shall be revolved during the measurements. The motion of the turntable shall not be synchronous with the rotation of the microphone boom.

5.6 Calibration of measurement system

Before the measurement of the equipment noise, the measurement set-up shall be calibrated in accordance with ISO 3741. Calibration at a single frequency is sufficient if the frequency response of the entire system, including the frequency range of the 16 kHz octave band is checked at intervals of not more than two years.

If an FFT analyser is calibrated with a single-frequency calibrator, care shall be taken to have all major sideband levels included in the calibration level.

5.7 Measurement of sound pressure level

The sound pressure level is measured in one-third-octave bands or, if discrete tones are present, in narrow bands which include the discrete tones. Measurements of the time-averaged sound pressure level along the circular microphone path shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained:

a) the band time-averaged sound pressure level with the equipment in operation,

b) the band time-averaged sound pressure levels of the background noise (including noise produced by ancillary equipment, if any); and

c) the band time-averaged sound pressure levels of the reference sound source (if required, see Clause 8).

True integration-averaging during a full sweep of the microphone is the preferred method. When using a narrow-band analyser that performs the analysis in consecutive time periods, each time period shall correspond to one revolution. The influence of measurement duration and corrections for background noise shall be taken into account in accordance with ISO 3741.

When FFT analysers are used, the analysis time is typically greater than the individual time window. For this reason, the total measurement time shall be increased, or individual measurements shall be repeated for three revolutions of the boom, each for a different starting point.

The mean value $\overline{L_p}$, of N measurements of the band time-averaged sound pressure level shall be calculated using Formula (1):

$$\overline{L_p} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_i} \right] \text{ dB} \quad (1)$$

where

L_i is the band time-averaged sound pressure level (reference: 20 μPa), in decibels, for the i-th measurement.

For the four orientations of the equipment under test, the mean value, $\overline{L_p}$ is obtained with $N = 4$. For the three revolutions of the boom, $\overline{L_p}$ is obtained using $N = 3$.

When a discrete tone is analysed, the moving microphone distributes the energy of the tone into sidebands of the tone frequency. In order to obtain the total tone level, the analyser bandwidth shall not be less than:

$$\Delta f = 2 f \frac{v}{c} \quad (2)$$

where

Δf is the minimum value of the analyser bandwidth, in hertz;

f is the centre frequency of the tone, in hertz;

c is the speed of sound, in metres per second;

v is the speed of the traversing microphone, in metres per second.

When using FFT or equivalent techniques for the analysis of the discrete tone(s), the bandwidth can be significantly narrower than given in Formula (2). In this case, the levels in the sidebands adjacent to the tone centre frequency which contribute to the tone level shall be added on an energy basis to obtain the total tone sound pressure level using Formula (3):

$$L_{tot} = 10 \lg \sum_{i=1}^{N_{sb}} 10^{0,1 L_i} \text{ dB} \quad (3)$$

where

L_{tot}	is the total sound pressure level (reference: 20 μPa) of the tone, in decibels;
L_i	is the sound pressure level (reference: 20 μPa) in an individual band, in decibels;
N_{sb}	is the number of sideband levels to be combined.

6 Method using measured reverberation time

6.1 General

A basic assumption of this method is that the reverberant component dominates the sound field at the microphone positions. Experiments show that in the 16 kHz octave band, the direct field might still be present. However, the microphone orientation specified in 5.4 significantly reduces the direct field contribution, and, therefore, the measured time-averaged sound pressure level is determined by the reverberant field. From the measured reverberation time which is determined by the absorption in air and by the room surfaces, the total room absorption is calculated. Although air absorption is the major part of the two, wall absorption can contribute to the total room absorption. At frequencies above 10 kHz, the absorption coefficient of the room, α_{room}, cannot be considered small compared to unity. Therefore, the Eyring equation (see Formula (5)) shall be used for the calculation of the room absorption instead of the simpler Sabine equation.

6.2 Measurement of reverberation time

The reverberation time, T, in seconds, of the reverberation test room with the equipment under test present shall be determined in those one-third-octave bands with centre frequencies between 12,5 kHz and 20 kHz which are of interest for the measurement of the equipment noise. When the equipment under test emits discrete tones, the reverberation time shall be measured at those frequencies in narrower bands, e.g. in one-twelfth octave bands. For each frequency band of interest, the average value of the reverberation times measured at three or more locations, equally spaced on the microphone path, shall be determined. The response time of the measuring instrument (e.g. a level recorder) shall be such that reverberation times shorter than 0,7 s can be measured.

6.3 Calculation of room absorption

The numerical value of the room constant, R, in square metres, for each band is calculated from the measured reverberation time as follows:

$$R = \frac{S \cdot \alpha_{room}}{1 - \alpha_{room}} \quad (4)$$

$$\alpha_{room} = 1 - e^{-0,16 V / (S \cdot T)} \quad (5)$$

where

S	is the numerical value of the total surface area, in square metres, of the room;
V	is the numerical value of the volume, in cubic metres, of the room;

T is the numerical value of the measured average reverberation time, in seconds;

α_{room} is the absorption coefficient of the room.

6.4 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 5.4 and 5.5, respectively.

6.5 Measurement of sound pressure level

Before the measurement of the equipment noise, the measurement set-up shall be calibrated as described in 5.6. The mean time-averaged sound pressure level, $\overline{L_p}$, shall be measured as described in 5.7. When the noise of the equipment under test is broad-band in character, a one-third-octave band analyser shall be used. When the noise of the equipment under test contains discrete frequencies, a narrow-band analyser providing analysis bandwidths of less than one-third-octave in width shall be used if the frequency of the tone is to be determined and/or when multiple tones are present.

6.6 Calculation of sound power level

The sound power level of the equipment shall be calculated in each band of interest from Formula (6):

$$L_W = \overline{L_{p(\mathrm{ST})}} - 10\lg\frac{4}{R}\ \mathrm{dB} \qquad (6)$$

where:

L_W is the band sound power level (reference: 1 pW) of the equipment in decibels ;

$\overline{L_{p(\mathrm{ST})}}$ is the mean band sound pressure level (reference: 20 µPa) of the four orientations of the equipment under test ("source under test"), in decibels, measured in accordance with 6.5;

R is the numerical value of the room constant in square meters, in accordance with 6.3.

7 Method using calculated air absorption

7.1 General

The basic assumption of this method is that the reverberant component dominates the sound field at the microphone positions. Experiments show that in the 16 kHz octave band the direct field might still be present. However, the microphone orientation specified in 5.4 significantly reduces the direct field contribution, and, therefore, the measured sound pressure level is determined by the reverberant field. Furthermore, it is assumed that the total room absorption is due only to the absorption in air. Therefore, this method is a simplification of the method described in 6.3 and avoids the measurement of the reverberation time. The room absorption is directly calculated from the air absorption coefficient given in Tables 1 and 2 for the temperature range of 18 °C to 27 °C. The equations for calculating the air absorption coefficient are given in Annex A.

7.2 Calculation of room constant

At frequencies of 10 kHz and above, essentially all of the absorption in a reverberation test room is due to air absorption. Under these conditions, the numerical value of the room constant, R, in square metres, for each frequency band of the reverberation test room is given by Formula (7):

$$R = \frac{8 \cdot \alpha \cdot V}{1 - \frac{8 \cdot \alpha \cdot V}{S}} \quad (7)$$

where

α is the numerical value of the air absorption coefficient, in nepers per metre; it is given in Tables 1 and 2 as a function of frequency, relative humidity and temperature of the air in the room;

S is the numerical value of the total surface area, in square metres, of the room;

V is the numerical value of the volume of the room, in cubic metres.

7.3 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 5.4 and 5.5, respectively.

7.4 Measurement of sound pressure level

The procedures of 6.5 shall be followed.

7.5 Calculation of sound power level

The procedures of 6.6 shall be followed.

Table 1 — Values of the air absorption coefficient (18 ºC to 22 ºC)

Frequency	Air absorption coefficient, α (Np/m), at an atmospheric pressure of 101, 325 kPa											
	Temperature: 18 ºC			Temperature: 20 ºC			Temperature: 21 ºC			Temperature: 22 ºC		
	Relative humidity			Relative humidity			Relative humidity			Relative humidity		
Hz	40	50	60	40	50	60	40	50	60	40	50	60
10 000	0,023 9	0,019 8	0,016 8	0,022 3	0,018 3	0,015 5	0,021 5	0,017 6	0,014 9	0,020 7	0,016 9	0,014 3
10 500	0,025 9	0,021 6	0,018 4	0,024 3	0,020 0	0,017 0	0,023 4	0,019 2	0,016 3	0,022 6	0,018 5	0,015 7
11 000	0,028 0	0,023 4	0,020 0	0,026 3	0,021 7	0,018 5	0,025 4	0,020 9	0,017 8	0,024 5	0,020 1	0,017 1
11 500	0,030 1	0,025 3	0,021 7	0,028 4	0,023 6	0,020 1	0,027 4	0,022 7	0,019 3	0,026 5	0,021 8	0,018 6
12 000	0,032 2	0,027 3	0,023 4	0,030 5	0,025 4	0,021 7	0,029 5	0,024 5	0,020 9	0,028 6	0,023 6	0,020 1
12 500	0,034 4	0,029 3	0,025 2	0,032 6	0,027 3	0,023 4	0,031 6	0,026 4	0,022 6	0,030 7	0,025 4	0,021 7
13 000	0,036 5	0,031 3	0,027 1	0,034 8	0,029 3	0,025 2	0,033 8	0,028 3	0,024 2	0,032 8	0,027 3	0,023 4
13 500	0,038 7	0,033 4	0,029 0	0,037 0	0,031 3	0,027 7	0,036 6	0,030 3	0,026 6	0,035 5	0,029 2	0,025 1
14 000	0,040 9	0,035 5	0,030 9	0,039 2	0,033 4	0,028 8	0,038 2	0,032 3	0,027 8	0,037 2	0,031 2	0,026 8
14 500	0,043 0	0,037 6	0,032 9	0,041 5	0,035 5	0,030 7	0,040 5	0,034 4	0,029 6	0,039 4	0,033 2	0,028 6
15 000	0,045 2	0,039 8	0,034 9	0,043 7	0,037 6	0,032 6	0,042 8	0,036 5	0,031 5	0,041 7	0,035 3	0,030 4
15 500	0,047 4	0,042 0	0,036 9	0,046 0	0,039 8	0,034 6	0,045 1	0,038 6	0,033 4	0,044 4	0,037 4	0,032 3
16 000	0,049 6	0,044 2	0,039 0	0,048 3	0,042 0	0,036 6	0,047 4	0,040 8	0,035 4	0,046 4	0,039 5	0,034 2
16 500	0,051 7	0,046 4	0,041 1	0,050 6	0,044 2	0,038 6	0,049 7	0,043 3	0,037 4	0,048 7	0,041 7	0,036 2
17 000	0,053 9	0,048 6	0,043 2	0,052 9	0,046 4	0,040 7	0,052 1	0,045 2	0,039 5	0,051 1	0,043 9	0,038 2
17 500	0,056 0	0,050 9	0,045 4	0,055 2	0,048 7	0,042 8	0,054 4	0,047 5	0,041 5	0,053 5	0,046 2	0,040 2
18 000	0,058 1	0,053 1	0,047 6	0,057 5	0,051 0	0,045 5	0,056 8	0,049 8	0,043 7	0,055 8	0,048 4	0,042 3
18 500	0,060 2	0,055 4	0,049 8	0,059 8	0,053 3	0,047 2	0,059 1	0,052 1	0,045 8	0,058 2	0,050 8	0,044 4
19 000	0,062 3	0,057 6	0,052 0	0,062 0	0,055 6	0,049 4	0,061 5	0,054 4	0,048 8	0,060 7	0,053 1	0,046 6
19 500	0,064 3	0,059 9	0,054 3	0,064 3	0,058 0	0,051 6	0,063 8	0,056 8	0,050 2	0,063 1	0,055 4	0,048 8
20 000	0,066 4	0,062 2	0,056 6	0,066 6	0,060 3	0,053 9	0,066 2	0,059 1	0,052 5	0,065 5	0,057 8	0,051 1
20 500	0,068 4	0,064 4	0,058 9	0,068 8	0,062 7	0,056 2	0,068 5	0,061 5	0,054 8	0,067 9	0,060 2	0,053 3
21 000	0,070 4	0,066 7	0,061 2	0,071 1	0,065 1	0,058 5	0,070 9	0,063 9	0,057 1	0,070 3	0,062 6	0,055 5
21 500	0,072 4	0,068 9	0,063 5	0,073 3	0,067 5	0,060 9	0,073 2	0,066 4	0,059 4	0,072 7	0,065 1	0,057 9
22 000	0,074 3	0,071 2	0,065 8	0,075 5	0,069 9	0,063 2	0,075 5	0,068 8	0,061 8	0,075 2	0,067 5	0,060 2
22 400	0,075 9	0,073 0	0,067 7	0,077 3	0,071 8	0,065 1	0,077 4	0,070 7	0,063 7	0,077 1	0,069 5	0,062 1

Table 2 — Values of the air absorption coefficient (23 ºC to 27 ºC)

Frequency	Air absorption coefficient, α (Np/m), at an atmospheric pressure of 101, 325 kPa											
	Temperature: 23 ºC			Temperature: 24 ºC			Temperature: 25 ºC			Temperature: 27 ºC		
	Relative humidity			Relative humidity			Relative humidity			Relative humidity		
Hz	40	50	60	40	50	60	40	50	60	40	50	60
10 000	0,019 9	0,016 2	0,013 8	0,019 1	0,015 6	0,013 3	0,018 4	0,015 1	0,012 9	0,017 1	0,014 4	0,012 1
10 500	0,021 7	0,017 8	0,015 1	0,020 9	0,017 1	0,014 6	0,020 1	0,016 5	0,014 1	0,018 7	0,015 3	0,013 2
11 000	0,023 6	0,019 4	0,016 5	0,022 8	0,018 7	0,015 9	0,021 9	0,018 8	0,015 4	0,020 3	0,016 7	0,014 4
11 500	0,025 6	0,021 1	0,017 9	0,024 7	0,020 3	0,017 3	0,023 8	0,019 5	0,016 7	0,022 1	0,018 2	0,015 6
12 000	0,027 6	0,022 7	0,019 4	0,026 6	0,021 9	0,018 7	0,025 7	0,021 1	0,018 1	0,023 9	0,019 7	0,016 9
12 500	0,029 6	0,024 5	0,020 9	0,028 6	0,023 6	0,020 2	0,027 6	0,022 8	0,019 5	0,025 7	0,021 2	0,018 2
13 000	0,031 7	0,026 3	0,022 5	0,030 7	0,025 4	0,021 7	0,029 7	0,024 5	0,021 1	0,027 6	0,022 8	0,019 6
13 500	0,033 9	0,028 2	0,024 2	0,032 8	0,027 2	0,023 3	0,031 7	0,026 3	0,022 5	0,029 6	0,024 5	0,021 1
14 000	0,036 1	0,030 1	0,025 9	0,035 5	0,029 1	0,025 5	0,033 9	0,028 1	0,024 1	0,031 6	0,026 2	0,022 5
14 500	0,038 3	0,032 1	0,027 6	0,037 2	0,031 1	0,026 6	0,036 6	0,033 0	0,025 7	0,033 7	0,028 8	0,024 4
15 000	0,040 6	0,034 1	0,029 4	0,039 4	0,033 3	0,028 4	0,038 2	0,031 9	0,027 4	0,035 8	0,029 8	0,025 6
15 500	0,042 9	0,036 2	0,031 2	0,041 7	0,035 5	0,030 1	0,040 5	0,033 8	0,029 1	0,038 8	0,031 6	0,027 2
16 000	0,045 2	0,038 3	0,033 1	0,044 4	0,037 1	0,032 2	0,042 8	0,035 9	0,030 9	0,040 2	0,033 5	0,028 9
16 500	0,047 6	0,040 4	0,035 5	0,046 4	0,039 2	0,033 8	0,045 1	0,037 9	0,032 7	0,042 5	0,035 5	0,030 6
17 000	0,049 9	0,042 6	0,036 9	0,048 7	0,041 3	0,035 7	0,047 4	0,044 0	0,034 6	0,044 8	0,037 5	0,032 3
17 500	0,052 3	0,044 8	0,038 9	0,051 1	0,043 5	0,037 7	0,049 8	0,042 1	0,036 5	0,047 1	0,039 5	0,034 1
18 000	0,054 8	0,047 1	0,041 1	0,053 6	0,045 7	0,039 7	0,052 2	0,044 3	0,038 4	0,049 5	0,041 6	0,036 6
18 500	0,057 2	0,049 4	0,043 1	0,056 6	0,048 8	0,041 7	0,054 7	0,046 5	0,040 4	0,051 9	0,043 7	0,037 8
19 000	0,059 6	0,051 7	0,045 2	0,058 5	0,050 3	0,043 8	0,057 2	0,048 8	0,042 4	0,054 3	0,045 9	0,039 8
19 500	0,062 1	0,054 4	0,047 3	0,060 9	0,052 6	0,045 9	0,059 7	0,051 1	0,044 5	0,056 8	0,048 1	0,041 7
20 000	0,064 6	0,056 4	0,049 5	0,063 4	0,054 9	0,048 8	0,062 2	0,053 4	0,046 6	0,059 3	0,050 3	0,043 7
20 500	0,067 7	0,058 8	0,051 7	0,066 6	0,057 3	0,050 2	0,064 7	0,055 8	0,048 7	0,061 8	0,052 6	0,045 8
21 000	0,069 5	0,061 2	0,054 4	0,068 5	0,059 7	0,052 4	0,067 2	0,058 2	0,050 9	0,064 4	0,054 9	0,047 8
21 500	0,072 2	0,063 7	0,056 3	0,071 1	0,062 2	0,054 7	0,069 8	0,060 6	0,053 1	0,066 9	0,057 3	0,055 0
22 000	0,074 5	0,066 1	0,058 6	0,073 5	0,064 6	0,057 7	0,072 4	0,063 3	0,055 3	0,069 5	0,059 7	0,052 1
22 400	0,076 5	0,068 1	0,060 5	0,075 6	0,066 6	0,058 8	0,074 4	0,065 5	0,057 1	0,071 6	0,061 6	0,053 8

8 Method using a reference sound source

8.1 Reference sound source

A reference sound source (RSS) shall be used which emits sufficient acoustical energy in the 16 kHz octave band to obtain a band time-averaged sound pressure level in the reverberation test room that is at least 10 dB above the background noise level. The sound power levels of the reference sound source shall be known and shall be determined in accordance with ISO 6926.

For the measurement of broad-band noise, the calibration shall be performed in one-third-octave bands.

For the measurement of discrete tones, the calibration or the reference sound source shall be performed in narrow bands (e.g. 100 Hz constant band-width or one-twelfth octave) and the sound power levels shall be reported per unit band-width (power spectral density).

8.2 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 5.4 and 5.5, respectively.

8.3 Installation of reference sound source

The location of the reference sound source in the reverberation test room shall be the same as for the equipment under test.

One single location and one orientation for the RSS are sufficient.

8.4 Measurement of sound pressure level

Before measuring the noise of the equipment under test and the noise of the reference sound source, the measurement set-up shall be calibrated as described in 5.6. The mean time-averaged sound pressure level, $\overline{L_p}$, shall be measured sequentially for the equipment under test and the reference sound source, as described in 5.7. When the noise of the equipment under test is broad-band in character, a one-third-octave band analyser shall be used. When the noise of the equipment under test contains discrete frequencies, a narrow-band analyser providing analysis bandwidths of less than one-third-octave in width shall be used. The same bandwidth shall be used for the measurements of the sound pressure level of the equipment under test and of the reference sound source. The band-width and filter characteristics of the analyser shall be reported.

8.5 Calculation of sound power level

8.5.1 Equipment emitting broad-band noise

The sound power level of each one-third-octave band of interest shall be calculated from Formula (8):

$$L_W = L_{W\text{(RSS)}} - \overline{L_{p\text{(RSS)}}} + \overline{L_{p\text{(ST)}}} \qquad (8)$$

where

L_W is the band sound power level (reference: 1 pW) of the equipment under test, in decibels;

$L_{W\text{(RSS)}}$ is the band sound power level (reference: 1 pW) of the calibrated reference sound source, in decibels as determined in accordance with 8.1;

$\overline{L_{p\text{(RSS)}}}$ is the mean band time-averaged sound pressure level (reference: 20 μPa) of the calibrated reference sound source, in decibels, measured in accordance with 5.7;

$\overline{L_{p\text{(ST)}}}$ is the mean band time-averaged sound pressure level (reference: 20 μPa) of the four orientations of the equipment under test, in decibels, measured in accordance with 5.7.

8.5.2 Equipment emitting discrete tone(s)

The sound power level shall be calculated for each frequency of interest from Formula (9):

$$L_W = L_{W\text{(RSS)}} - \overline{L_{p\text{(RSS)}}} + \overline{L_{p\text{(ST)}}} + 10\,\lg\left(\Delta F / 1\,\text{Hz}\right)\ \text{dB} \qquad (9)$$

where

L_W is the band sound power level (reference: 1 pW) of the equipment under test, in decibels;

$L_{W\text{(RSS)}}$ is the sound power level (reference: 1 pW) per unit band-width of the calibrated reference sound source, for the frequency of interest, in decibels, as determined in accordance with 8.1;

$\overline{L_{p\text{(RSS)}}}$ is the mean time-averaged sound pressure level (reference: 20 μPa) of the calibrated reference sound source, in decibels, measured in accordance with 5.7, in narrow bands;

$\overline{L_{p\text{(ST)}}}$ is the mean time-averaged sound pressure level (reference: 20 μPa) of the four orientations of the equipment under test, in decibels, measured in accordance with 5.7 in narrow bands;

ΔF is the bandwidth of a constant bandwidth analyser (e.g. an FFT analyser) used for the sound pressure level measurements; it is the noise bandwidth of the filter, not the bandwidth between half-power points. For constant percentage bandwidth analysers (e.g. 1/24$^{\text{th}}$ octave band), this parameter can be assumed to be equal to 1 Hz. The bandwidth of an FFT shall be 112 Hz or less.

NOTE The noise bandwidth is the bandwidth of the ideal (rectangular) filter that would pass the same signal power as the real filter when each is driven by a stationary random-noise signal having a constant power spectral density.

9 Method using a free field over a reflecting plane

9.1 General

A method that uses a free field over a reflecting plane exists. This technique is described in ECMA-74 and ISO 3744. A hemi-anechoic room shall be used for the measurements described hereafter. The test environment shall provide an essentially free field over a reflecting plane. Criteria for suitable test environments are defined in ISO 3744.

NOTE 1 Suitable test environments are also defined in ISO 3745[1].

NOTE 2 A small error might be introduced by this procedure due to interference caused by the reflecting plane, but this can be ignored.

NOTE 3 Although air absorption plays an important role in the high-frequency range, its effect is relatively small for a measurement radius of less than 2 m in a free field over a reflecting plane.

9.2 Meteorological conditions

The requirements of ISO 3744 as applicable shall be followed.

For equipment whose noise emissions intentionally vary with ambient temperature (e.g. by varying the speeds of air moving devices), the room temperature during the test measurement shall be 23 °C ± 2 °C or, if the room temperature is outside these limits, then the fan shall be adjusted to the speed for an ambient temperature of 23 °C ± 2 °C.

The requirements of ISO 3744 as applicable shall be followed.

– Static pressure: 86 kPa to 106 kPa

– Temperature: 15 °C to 30 °C.

– Relative humidity: 40 % to 70 %.

NOTE As indicated in Tables 1 and 2, higher temperatures and higher humidity will tend to minimize the effects of atmospheric absorption.

9.3 Instrumentation

The sound measuring system, including the microphone, should have a flat free-field frequency response for normally incident sound in the 16 kHz octave band. The microphone response shall be corrected to give a flat frequency response within the 16 kHz octave band. The tolerances after correction shall be within ±1,0 dB in the frequency range 11,2 kHz to 22,4 kHz.

NOTE 1 To meet this requirement a microphone with an outer diameter of 13,2 mm or less is usually required.

When the noise of the equipment under test is broad-band in character, an analyser with a bandwidth of one-third-octave or less shall be used. When the noise of the equipment under test contains discrete tones, a narrow-band analyser which provides bandwidths of less than one-third-octave in width shall be used to determine the frequency of the tone(s) and to enhance the signal-to-noise ratio.

NOTE 2 For narrow-band analysis, an analyser with a bandwidth equal to, or less than, one-twelfth octave band is appropriate. Digital analysers using fast Fourier transform (FFT) or equivalent techniques can be useful, particularly when the analyser combines narrow-band analysis and averaging.

9.4 Installation and orientation of microphone

The microphone(s) shall be installed on an imaginary hemisphere which has its origin in the reflecting plane. The normal to the diaphragm of the microphone(s) shall pass through the origin of the measurement hemisphere. One of the following three microphone arrangements shall be used:

a) a rotating boom that moves the microphone(s) along coaxial circular paths on the imaginary hemisphere as specified in ISO 3744 with a minimum of ten heights; the traversing period as required by ISO 3744. Longer periods might be suitable to reduce background noise of the drive mechanism.

b) a fixed microphone array with the equipment under test mounted on a rotating turntable. The fixed microphones are arranged so that coaxial circular paths are created by the rotating turntable. The coaxial circular path arrangement specified in ISO 3744 with a minimum of 10 heights shall be used.

c) when using fixed microphone positions with the equipment under test in a fixed position, the preferred microphone positions given in ISO 3744 shall be used for all sources.

NOTE 1 If preliminary investigation reveals that the source radiates noise in a highly directional manner, accuracy might be improved by changing the orientation of the source, relative to the microphone path, repeating the measurement and averaging the results using Formula (1).

Care shall be taken to ensure that there is no electrical pick-up by the measurement instrumentation which can interfere with the sound pressure level measurement.

NOTE 2 A test with a dummy microphone, and with the equipment under test in operation, can determine the electrical background level.

9.5 Installation of equipment

The equipment under test shall be placed on the reflecting floor. The projection of the geometric centre of the equipment on the floor shall be the origin of the measurement hemisphere with radius r (see 9.4).

9.6 Calibration of measurement system

Before measuring the noise of the equipment under test, the measurement set-up shall be calibrated in accordance with ISO 3744. Calibration at a single frequency is sufficient if the frequency response of the entire system, including the frequency range of the 16 kHz octave band, is checked at intervals of not more than two years.

If an FFT analyser is calibrated with a single-frequency calibrator, care shall be taken to have all major sideband levels included in the calibration level.

9.7 Measurement of sound pressure level

The time-averaged sound pressure level shall be measured in one-third-octave bands or in narrow bands which contain any discrete tones. Measurements of the time-averaged sound pressure level in accordance with 9.3 shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained:

a) the band time-averaged sound pressure levels with the equipment in operation;

b) the band time-averaged sound pressure levels of the background noise (including noise produced by ancillary equipment, if any).

True integration-averaging during a full sweep of the microphone or during a full revolution of the source is the preferred method. If the source is rotated, the mean time-averaged sound pressure level shall be determined for one revolution of the source. The influence of measurement duration and corrections for background noise shall be taken into account in accordance with ISO 3744.

If microphone arrangements in accordance with 9.4 item a) or item b) are used, the minimum integration time shall be 30 s. If fixed microphone locations in accordance with 9.4 item c) are used, the minimum integration time shall be 8 s at each location or a total integration time of at least 30 s if the measurements are made simultaneously at each microphone.

When FFT analysers are used, the analysis time is typically greater than the individual ti item me window. For this reason, the total measurement time shall be increased, or individual measurements shall be repeated as specified in 5.7 for microphone arrangements in accordance with 9.4 item a) or b). For microphone arrangements in accordance with 9.4 item c), the minimum integration time shall be increased to 30 s.

Furthermore, when using FFT or equivalent techniques for the analysis of discrete tone(s), the levels in the sidebands shall be considered as described in 5.7, Formula (3).

The bandwidth and filter characteristics of the analyser shall be reported.

9.8 Calculation of surface sound pressure level and sound power level

The procedures of ECMA-74 and ISO 3744 shall be used.

If the measurement radius, r, is greater than 2 m, the surface sound pressure level determined in accordance with ISO 3744 shall be corrected by adding the absorption correction K_α before determining the sound power level. K_α is determined from Formula (10):

$$K_\alpha = r \cdot \alpha \qquad (10)$$

where

α is the absorption coefficient, in decibels per metre, before determining the sound power level.

10 Calculation of sound power level under reference meteorological conditions

10.1 Reverberation test rooms

Reduced static pressure creates a bias in the sound power level. The sound power levels corresponding to the reference static pressure of 101,325 kPa and reference atmospheric temperature 23,0 °C shall be calculated in accordance with ISO 3741.

10.2 Hemi-anechoic rooms

Reduced static pressure creates a bias in the sound power level. At altitudes greater than 500 m above sea level the sound power levels corresponding to the reference static pressure of 101,325 kPa and reference atmospheric temperature 23,0 °C shall be calculated in accordance with ISO 3744.

11 Measurement uncertainty

The uncertainties of sound power levels, $u(L_W)$ in decibels, determined in accordance with this Standard are estimated by the total standard deviation, σ_{tot} , in decibels:

$$u\left(L_W\right) \approx \sigma_{\text{tot}} \quad (11)$$

This total standard deviation is obtained using the modelling approach described in ISO/IEC Guide 98-3. This requires a mathematical model, which in case of lack of knowledge, can be replaced by results from measurements, including results from round robin tests.

Measurements carried out in accordance with the methods in this Standard yield standard deviations of reproducibility for the sound power level in the 16 kHz octave band equal to or less than 3 dB.

NOTE The standard deviation given above reflects the cumulative effects of all causes of measurement uncertainty, including variations from laboratory to laboratory, but excludes variations in the sound power level from equipment to equipment or from test to test, which can be caused, for example, by changes in the installation or operating conditions of the equipment. The reproducibility and repeatability of the test results for the same piece of equipment and the same measurement conditions can be considerably better (i.e. smaller standard deviations) than the uncertainty given above. The reproducibility values are based on the data [3] and measurements which were taken at other laboratories in the preparation of the first edition of ISO 9295.

The guidance on the development of information on measurement uncertainty contained in the relevant clauses of ISO 3741 and ISO 3744, as applicable, can be used for this Standard with adjustments for measurement in the 16 kHz octave band.

12 Information to be recorded

12.1 General

The following information shall be recorded, when applicable, for all measurements carried out in accordance with this Standard.

12.2 Equipment under test

The following information shall be recorded:

a) description of the equipment under test (including principal dimensions);

b) operating conditions with reference to ECMA-74 or ISO 3741 or ISO 3744; if the equipment has multiple operating modes, description of each individual mode for which measurements have been performed;

c) installation conditions;

d) location(s) of equipment in the test environment.

12.3 Acoustic environment

The following information shall be recorded:

a) description of the acoustic environment, dimensions, shape and acoustical characteristics (absorption and/or reverberation time in frequency bands) of the room;

b) description of the microphone arrangement;

c) air temperature, expressed in degrees Celsius, relative humidity, expressed as a percentage, and static pressure expressed in pascals.

12.4 Instrumentation

The following information shall be recorded:

a) equipment used for the measurement, including name, type, serial number and manufacturer;

b) type and bandwidth of the frequency analyser;

c) frequency response of the instrumentation system;

d) method used for checking the calibration of the microphone(s) and other system components; date and place of calibration;

e) type and calibration of reference sound source, and date and place of calibration;

f) method used for determining the mean time-averaged sound pressure level.

12.5 Acoustical data

The following information shall be recorded:

a) method used for determining sound power level;

b) type of noise in accordance with Table 3;

c) sound power level(s) (reference: 1 pW) under reference meteorological conditions, in decibels, in one-third-octave bands and/or narrow bands together with the frequency of the tone(s). The requirements of ISO 3741 or ISO 3744, as applicable, shall be followed, including calculation of the noise emission at the reference meteorological conditions;

d) the expanded measurement uncertainty of the results, as required by ISO 3741 or ISO 3744, as applicable;

e) date, time and place where the measurements were performed, and the name of the person performing the measurements.

13 Information to be reported

The report shall contain the statement that the sound power levels have been obtained in full conformance with one or more of the methods described in this Standard. This report shall contain, as a minimum, the following information:

a) name(s) and model number(s) of the equipment under test;

b) type of noise in accordance with Table 3;

c) sound power level(s) (reference: 1 pW) under reference meteorological conditions,) in decibels, in one-third-octave bands and/or narrow bands together with the frequency of any tones having levels within 10 dB of the greatest tone level;

d) detailed description of operating conditions of the equipment under test with reference to specific subclause of ECMA-74, if applicable.

NOTE A description such as for example “operating and installation conditions in accordance with C.20 of ECMA-74:2015, 13th edition can be used.

Table 3 — Type of noise and determination of sound power levels

Type of noise in the frequency range of the octave bands centred at		**Sound power level to be determined**
125 Hz to 8 kHz	16 kHz	
Broad-band or narrow-band noise	No significant noise	A-weighted level (125 Hz to 8 kHz octave bands) in accordance with ECMA-74
	Broad-band noise	A-weighted level (125 Hz to 8 kHz octave bands in accordance with ECMA-74, and one-third-octave-band sound power level in 16 kHz octave band in accordance with the procedure of this Standard.
Broad-band or narrow-band noise	Discrete tone	A-weighted level (125 Hz to 8 kHz octave bands) in accordance with ECMA-74 and the level and frequency of the discrete tone in accordance with this Standard.
	Multiple tones	A-weighted level (125 Hz to 8 kHz octave bands) in accordance with ECMA-74 and the levels and frequencies of all tones in the 16 kHz octave band that are within 10 dB of the highest tone level in the band in accordance with this Standard.
No significant noise	Discrete tone	Level and frequency of the discrete tone in the 16 kHz octave band in accordance with this Standard.
	Multiple tones	Levels and frequencies of all tones in the 16 kHz octave band that are within 10 dB of the highest tone level in the band in accordance with this Standard.

[a] For noise in the 125 Hz to 8 kHz octave bands, sound power level in one-third-octave bands and in octave bands can also be reported in accordance with ECMA-74.

[b] A significant noise contribution not within the 125 Hz to 8 kHz octave band lies outside the scope of ECMA-74; in that case, only this Standard is applicable.

Annex A
(normative)

Calculation of air absorption coefficient

Values of the air absorption coefficient, α, in nepers per metre, are calculated from Formulae (A.1) to (A.5) hereafter. Values of the frequency f, absolute temperature T, relative humidity h_r and static pressure p_s shall be known.

Symbols:

T_{01} triple-point isotherm temperature (= 273,16 K)

T_0 reference atmosphere temperature (= 293,15 K)

T atmospheric temperature, in kelvin

p_{s0} reference static pressure (= 101,325 kPa)

p_{sat} saturation vapour pressure, in kilopascal

p_s static pressure, in kilopascal

h molar concentration of water vapour, in per cent

h_r relative humidity, in per cent

$f_{r,O}$ oxygen relaxation frequency, in hertz

$f_{r,N}$ nitrogen relaxation frequency, in hertz

f frequency, in hertz

This calculation shall be based on ISO 9613-1. Compute lg(p_{sat} / p_{s0}) from Formula (A.1):

$$\lg\left(\frac{p_{sat}}{p_{s0}}\right) = -6{,}834\,6\left(\frac{T_{01}}{T}\right)^{1{,}261} + 4{,}615\;1 \qquad \text{(A.1)}$$

Compute h, in per cent, from Formula (A.2):

$$h = h_r \frac{\left(\frac{p_{sat}}{p_{s0}}\right)}{\left(\frac{p_s}{p_{s0}}\right)} \qquad \text{(A.2)}$$

Compute the numerical values of $f_{r,O}$ and $f_{r,N}$, in hertz, from Formulae (A.3) and (A.4):

$$f_{r,O} = \frac{p_s}{p_{s0}}\left(24 + 4{,}04 \times 10^4 \times h \times \frac{0{,}02 + h}{0{,}391 + h}\right) \qquad \text{(A.3)}$$

$$f_{r,N} = \frac{p_s}{p_{s0}} \left(\frac{T}{T_0}\right)^{-1/2} \times \left\{9 + 280 \times h \times \exp\left\{-4{,}170\left[\left(\frac{T}{T_0}\right)^{-1/3} - 1\right]\right\}\right\} \tag{A.4}$$

Compute the numerical value of the air absorption coefficient, α, in nepers per metre, from Formula (A.5):

$$\alpha = f^2 \left[1{,}84 \times 10^{-11} \times \left(\frac{p_s}{p_{s0}}\right)^{-1} \times \left(\frac{T}{T_0}\right)^{1/2} + \left(\frac{T}{T_0}\right)^{-5/2} \times \left(\frac{1{,}275 \times 10^{-2} \times \exp(-2\ 239{,}1/T)}{f_{r,O} + \frac{f^2}{f_{r,O}}} + \frac{1{,}068 \times 10^{-1} \times \exp(-3\ 352/T)}{f_{r,N} + \frac{f^2}{f_{r,N}}}\right)\right] \tag{A.5}$$

The conversion of the numerical values of absorption coefficient α (Np/m), in nepers per metre, to the numerical values of absorption coefficient α (dB/m), in decibels per metre, is given by multiplying the value of α in Np/m by 8,686 to obtain the value of α in dB/m.

Bibliography

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

[2] ISO 7779, *Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment*

[3] Gaunt, D.S. and Woerhle, K.K, *Measurement of high frequency noise in hemi-anechoic chambers and reverberation rooms*, Proc. INTER-NOISE 84, 1255-1260, 1984