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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Acoustics — Measurement of high-frequency noise emitted by computer and business equipment

Acoustique — Mesurage du bruit à haute fréquence émis par les matériels informatiques et de bureau

Reference number
ISO 9295 : 1988 (E)

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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 9295 was prepared by the European Computer Manufacturers Association (as Standard ECMA-108) and was adopted, under a special "fast-track procedure", by Technical Committee ISO/TC 43, *Acoustics*, in parallel with its approval by the ISO member bodies.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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INTERNATIONAL STANDARD ISO 9295 : 1988 (E)

Acoustics — Measurement of high-frequency noise emitted by computer and business equipment

0 Introduction

Some computer and business 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. switching power supplies and video display units). The measured levels are not frequency-weighted. However, when there are significant contributions in the octave bands having centre frequencies between 125 Hz and 8 kHz, and, in addition, there is a contribution in the 16 kHz band which is broad-band in character, the A-weighted sound power level may be calculated with the contribution of the 16 kHz octave band included. The principal objective of this International Standard is to prescribe methods for measuring the levels and frequencies of tones which are contained within the 16 kHz octave band.

1 Scope and field of application

This International Standard specifies four methods for the determination of the sound power levels of high-frequency noise emitted by computer and business equipment in the frequency range covered by the octave band centred at 16 kHz. They are complementary to the methods described in ISO 7779. The first three methods are based on the reverberation room technique described in clause 5 of ISO 7779 : 1988. The fourth method makes use of a free field over a reflecting plane as described in clause 6 of ISO 7779 : 1988.

The test conditions which prescribe the installation and operation of the equipment are those specified in ISO 7779.

While the four methods described in this International Standard are particularly suitable for computer and business equipment, they may also be applied to other types of equipment. This International Standard specifies methods for the determination of sound power levels in the frequency range covered by the octave band centred at 16 kHz which includes frequencies between 11,2 kHz and 22,4 kHz.

NOTE — The sound power level in the 16 kHz octave band determined according to this International Standard typically is subject to a standard deviation of approximately 3 dB.

A method for the measurement of high-frequency noise is in conformance with this International Standard if it satisfies all the mandatory requirements of one of the four methods described herein and if the information recorded and reported is that specified in clauses 8, 9 and 10, respectively.

2 References

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.* 1)

ISO 7779, *Acoustics — Measurement of airborne noise emitted by computer and business equipment.*

3 Requirements for measurements in a reverberation room

3.1 General

Three methods are described using the reverberation room technique of clause 5 of ISO 7779 : 1988. The first and the second methods are usually called "direct" methods because they use directly measured or calculated reverberation times. The third method is a so-called comparison method. 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 average sound pressure level in the reverberant field.

As instrumentation and basic measurement techniques are the same for all three methods, they are summarized in 3.2 to 3.6. Additional requirements specific to each method are given separately. For additional information on instrumentation, refer to ISO 7779.

3.2 Instrumentation

The microphone shall have a flat frequency response for randomly incident sound in the 16 kHz octave band. The tolerances shall be within ± 2,0 dB in the frequency range 11,4 kHz to 22,8 kHz.

NOTE — To meet this requirement, a microphone with a diameter of 13 mm or less is usually required.

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1) To be published.

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 frequencies, a narrow-band analyser which provides bandwidths 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 — 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 may be useful, particularly when the analyser combines narrow-band analysis and averaging.

3.3 Installation and orientation of microphone

The microphone shall be mounted on 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 on the end of the boom pointing upwards in such a way that the normal to its diaphragm is parallel to the axis of rotation. The period of rotation shall be at least 30 s.

Longer paths and traversing periods than the minimum values may 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 would interfere with the sound pressure level measurement.

NOTE — A test with a dummy microphone, and with the equipment under test in operation, is recommended to determine the electrical background level.

3.4 Installation and orientation of equipment

Place the equipment on the floor of the reverberation 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 :

a) Operator side facing the centre of the microphone path.

b) Equipment turned clockwise by 90°.

c) Equipment turned clockwise by 180°.

d) Equipment turned clockwise by 270°.

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

3.5 Calibration of measurement system

Before the measurement of the equipment noise, the measurement set-up shall be calibrated according to 5.4.6 of ISO 7779 : 1988. 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.

3.6 Measurement of sound pressure level

The sound pressure level is measured in one-third octave bands or in narrow bands which include any discrete tones. Measurements of the 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 sound pressure levels with the equipment in operation.

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

c) The band sound pressure levels of the reference sound source (if required : see clause 6).

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 according to 5.7 of ISO 7779 : 1988.

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 average value, L_p, of N measurements of the sound pressure level shall be calculated using the equation :

$$L_p = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{(L_i/10)} \right] \qquad \ldots(1)$$

where L_i is the sound pressure level, in decibels (reference : 20 μPa) for the ith measurement.

For the four orientations of the equipment under test, the average value of L_p is obtained with $N = 4$. For the three revolutions of the boom, 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 level, the analyser bandwidth shall not be less than :

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

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 may be significantly narrower than given above. 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 level using the following equation :

$$L_{\text{tot}} = 10 \lg \sum_{i=1}^{N} 10^{(L_i/10)} \qquad \ldots(3)$$

where

L_{tot} is the total sound level, in decibels (reference : 20 µPa);

L_i is the sound pressure level in an individual band, in decibels (reference : 20 µPa);

N is the number of sideband levels to be combined.

4 Method using measured reverberation time

4.1 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 may still be present. However, the microphone orientation specified in 3.3 significantly reduces the direct field contribution, and, therefore, the measured 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 may contribute to the total room absorption. At frequencies above 10 kHz, the absorption coefficient of the room, α, cannot be considered small compared to unity. Therefore, the Eyring equation [see equation (4)] shall be used for the calculation of the room absorption instead of the simpler Sabine equation.

4.2 Measurement of reverberation time

The reverberation time, T, in seconds, of the reverberation 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 1/12 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.

4.3 Calculation of room absorption

The room constant R for each band is calculated from the measured reverberation time as follows :

$$R = \frac{S \times \alpha}{1 - \alpha} \qquad \ldots(4)$$

$$\alpha = 1 - e^{-0,16\, V/(S \times T)} \qquad \ldots(5)$$

where

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

V is the volume of the room, in cubic metres;

T is the measured average reverberation time, in seconds;

α is the absorption coefficient of the room.

4.4 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 3.3 and 3.4, respectively.

4.5 Measurement of sound pressure level

Before the measurement of the equipment noise, the measurement set-up shall be calibrated as described in 3.5. The average sound pressure level, L_p, shall be measured as described in 3.6. 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 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.

During these measurements, the room temperature and the relative humidity shall be within ± 1 °C and ± 2,5 %, respectively, of the values present during the reverberation time measurements.

4.6 Calculation of sound power level

The sound power level of the equipment shall be calculated in each band of interest from the following equation :

$$L_W = L_p - 10 \lg \frac{4}{R} \qquad \ldots(6)$$

where

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

L_p is the average band sound pressure level for the four orientations of the equipment under test, in decibels (reference : 20 µPa), measured according to 4.5;

R is the room constant according to 4.3.

5 Method using calculated air absorption

5.1 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 may still be present. However, the microphone orientation specified in 3.3 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 4.3 and avoids the measurement of the reverberation time. The room absorption is directly calculated from the air absorption coefficient given in table 1. The equations for calculating the air absorption coefficient are given in annex B.

5.2 Calculation of room constant

At frequencies of 10 kHz and above, essentially all of the absorption in a reverberation room is due to air absorption. Under these conditions, the room constant, R, of the reverberation room is given by :

$$R = \frac{8 \times a \times V}{1 - \dfrac{8 \times a \times V}{S}} \qquad \ldots(7)$$

where

a is the air absorption coefficient, in nepers per metre; a is given in table 1 as a function of frequency, relative humidity and temperature of the air in the room;

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

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

5.3 Temperature and humidity conditions during measurements

The values of room temperature and relative humidity used for the calculation of room constant shall be within ± 1 °C and ± 2,5 %, respectively, of the values during the measurement.

5.4 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 3.3 and 3.4, respectively.

5.5 Measurement of sound pressure level

Before the equipment noise is measured, the measurement setup shall be calibrated as described in 3.5. The average sound pressure level, L_p, shall be measured as described in 3.6. 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 less than one-third octave in width shall be used to determine the level and frequency of the tone(s) and to determine the level and frequency of each tone when multiple tones are present. The bandwidth and filter characteristics used shall be reported.

Table 1 — Air absorption coefficients

Frequency Hz	Air absorption coefficient, a (Np/m), at an atmospheric pressure of 101,325 kPa								
	Temperature : 18 °C			Temperature : 20 °C			Temperature : 22 °C		
	Relative humidity			Relative humidity			Relative humidity		
	40 %	50 %	60 %	40 %	50 %	60 %	40 %	50 %	60 %
10 000	0,022 2	0,018 3	0,015 6	0,020 6	0,016 9	0,014 4	0,019 1	0,015 7	0,013 4
10 500	0,024 1	0,020 0	0,017 0	0,022 5	0,018 5	0,015 8	0,020 9	0,017 1	0,014 6
11 000	0,026 1	0,021 7	0,018 5	0,024 4	0,020 1	0,017 2	0,022 7	0,018 7	0,016 0
11 500	0,028 1	0,023 5	0,020 1	0,026 4	0,021 9	0,018 7	0,024 6	0,020 3	0,017 3
12 000	0,030 2	0,025 4	0,021 8	0,028 4	0,023 6	0,020 2	0,026 5	0,021 9	0,018 8
12 500	0,032 3	0,027 3	0,023 4	0,030 5	0,025 4	0,021 8	0,028 5	0,023 6	0,020 2
13 000	0,034 5	0,029 2	0,025 2	0,032 6	0,027 3	0,023 4	0,030 6	0,025 4	0,021 8
13 500	0,036 6	0,031 2	0,027 0	0,034 7	0,029 2	0,025 1	0,032 7	0,027 2	0,023 4
14 000	0,038 8	0,033 3	0,028 8	0,036 9	0,031 1	0,026 8	0,034 8	0,029 1	0,025 0
14 500	0,041 0	0,035 3	0,030 7	0,039 1	0,033 1	0,028 6	0,037 0	0,031 0	0,026 7
15 000	0,043 2	0,037 4	0,032 6	0,041 4	0,035 2	0,030 4	0,039 2	0,032 9	0,028 4
15 500	0,045 4	0,039 5	0,034 5	0,043 6	0,037 3	0,032 3	0,041 4	0,034 9	0,030 1
16 000	0,047 6	0,041 7	0,036 5	0,045 9	0,039 4	0,034 2	0,043 7	0,037 0	0,032 0
16 500	0,049 8	0,043 9	0,038 5	0,048 2	0,041 5	0,036 1	0,046 0	0,039 1	0,033 8
17 000	0,052 1	0,046 1	0,040 6	0,050 5	0,043 7	0,038 1	0,048 3	0,041 2	0,035 7
17 500	0,054 3	0,048 3	0,042 7	0,052 8	0,045 9	0,040 2	0,050 7	0,043 3	0,037 6
18 000	0,056 5	0,050 5	0,044 8	0,055 1	0,048 2	0,042 2	0,053 0	0,045 5	0,039 6
18 500	0,058 7	0,052 8	0,047 0	0,057 5	0,050 4	0,044 3	0,055 4	0,047 7	0,041 6
19 000	0,060 9	0,055 1	0,049 2	0,059 8	0,052 7	0,046 4	0,057 8	0,050 0	0,043 7
19 500	0,063 0	0,057 3	0,051 4	0,062 1	0,055 0	0,048 6	0,060 3	0,052 3	0,045 8
20 000	0,065 2	0,059 6	0,053 6	0,064 5	0,057 4	0,050 8	0,062 7	0,054 6	0,047 9
20 500	0,067 4	0,061 9	0,055 9	0,066 8	0,059 7	0,053 0	0,065 1	0,056 9	0,050 1
21 000	0,069 5	0,064 2	0,058 1	0,069 1	0,062 1	0,055 3	0,067 6	0,059 3	0,052 3
21 500	0,071 6	0,066 6	0,060 4	0,071 5	0,064 5	0,057 6	0,070 0	0,061 7	0,054 5
22 000	0,073 8	0,068 9	0,062 7	0,073 8	0,066 8	0,059 9	0,072 5	0,064 1	0,056 7
22 400	0,075 4	0,070 7	0,064 6	0,075 6	0,068 8	0,061 7	0,074 5	0,066 1	0,058 6

5.6 Calculation of sound power level

The sound power level for each frequency band of interest shall be calculated from the following equation :

$$L_W = L_p - 10 \lg \frac{4}{R} \qquad \ldots(8)$$

where

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

L_p is the average band sound pressure level, in decibels (reference : 20 µPa), measured according to 5.5;

R is the room constant calculated in 5.2.

6 Method using a reference sound source

6.1 Reference sound source

A reference sound source (RSS) shall be used which emits sufficient acoustical energy in the 16 kHz octave band to obtain an average band pressure level in the reverberation 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 of the reference sound source shall be performed in narrow bands (e.g. 100 Hz constant bandwidth or one-twelfth octave) and the sound power levels shall be reported per unit bandwidth (power spectral density).

6.2 Installation of microphone and equipment

The microphone and the equipment under test shall be installed as described in 3.3 and 3.4, respectively.

6.3 Installation of reference sound source

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

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

6.4 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 3.5. The average sound pressure level, L_p, shall be measured sequentially for the equipment under test and the reference sound source, as described in 3.6. 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 less than one-third octave wide 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 bandwidth and filter characteristics of the analyser shall be reported.

During these measurements, the temperature and the relative humidity of the room shall be kept constant within ± 1 °C and ± 2,5 %, respectively.

6.5 Calculation of sound power level

6.5.1 Equipment emitting broad-band noise

The sound power level of each one-third octave band of interest shall be calculated from the following equation :

$$L_W = L_W(\text{RSS}) - L_p(\text{RSS}) + L_p \qquad \ldots(9)$$

where

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

$L_W(\text{RSS})$ is the sound power level of the calibrated reference sound source, in the one-third octave bands, in decibels (reference : 1 pW);

$L_p(\text{RSS})$ is the average sound pressure level of the calibrated reference sound source, in decibels (reference : 20 µPa), measured according to 3.6, in one-third octave bands;

L_p is the average sound pressure level for the four orientations of the equipment under test, in decibels (reference : 20 µPa), measured according to 3.6, in one-third octave bands.

6.5.2 Equipment emitting discrete frequency tone(s)

The sound power level shall be calculated for each frequency of interest from the following equation :

$$L_W = L_W(\text{RSS}) - L_p(\text{RSS}) + L_p + 10 \lg \Delta F \qquad \ldots(10)$$

where

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

$L_W(\text{RSS})$ is the sound power level per unit bandwidth of the calibrated reference sound source, for the frequency of interest, in decibels (reference : 1 pW);

$L_p(\text{RSS})$ is the average sound pressure level of the calibrated reference sound source, in decibels (reference : 20 µPa), measured according to 3.6 in narrow bands;

L_p is the average sound pressure level for the four orientations of the equipment under test, in decibels (reference : 20 µPa), measured according to 3.6 in narrow bands;

ΔF is the bandwidth of the analyser used for the sound pressure level measurements; ΔF is the noise bandwidth of the filter, not the bandwidth between half-power points.

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.

7 Method using a free field over a reflecting plane

7.1 General

One method is described which uses a free field over a reflecting plane. This technique is described in clause 6 of ISO 7779 : 1988. A semi-anechoic room shall be used for the measurements described in this clause.

NOTES

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

2 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.

7.2 Instrumentation

The microphone shall have a flat free-field frequency response for normally incident sound in the 16 kHz octave band. The tolerances shall be within ± 2,0 dB in the frequency range 11,4 kHz to 22,8 kHz.

NOTE — To meet this requirement, a microphone with a diameter of 13 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 frequencies, a narrow-band analyser which provides bandwidths 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 — 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 may be useful, particularly when the analyser combines narrow-band analysis and averaging.

7.3 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 five coaxial circular paths on the imaginary hemisphere. This microphone arrangement is shown in annex A. The traversing period should be at least 30 s. Longer periods may be suitable to reduce background noise of the drive mechanism.

b) A fixed microphone array as shown in annex A with the equipment under test mounted on a rotating turntable.

c) A fixed microphone array according to arrangement 4 of annex B of ISO 7779 : 1988 with a fixed position for the equipment under test.

NOTE — If preliminary investigation reveals that the source is highly directional, accuracy may be improved by tilting the source, repeating the measurement, and averaging the results using equation (1).

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

NOTE — A test with a dummy microphone, and with the equipment under test in operation, is recommended to determine the electrical background level.

7.4 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 is the origin of the measurement hemisphere with radius r (see 7.3).

7.5 Calibration of measurement system

Before measuring the noise of the equipment under test, the measurement set-up shall be calibrated according to 6.4.5 of ISO 7779 : 1988. 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.

7.6 Measurement of sound pressure level

The sound pressure level shall be measured in one-third octave bands or in narrow bands which contain any discrete tones. Measurements of the sound pressure level according to 7.3 shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained :

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

b) the band 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 average 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 according to 6.7 of ISO 7779 : 1988.

If microphone arrangements according to 7.3 a) or b) are used, the minimum integration time shall be 30 s. If fixed microphone locations according to 7.3 c) are used, the minimum integration time shall be 8 s.

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 as specified in 3.6 for microphone arrangements according to 7.3 a) or b). For microphone arrangements according to 7.3 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 3.6, equation (3).

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

During these measurements, the temperature and the relative humidity of the room shall be kept constant to within ± 1 °C and ± 2,5 %, respectively.

7.7 Calculation of surface sound pressure level

From the sound pressure levels measured at the individual microphone locations or on the microphone paths, the surface sound pressure level in each frequency band of interest is calculated according to 6.9 of ISO 7779 : 1988, using the following equation :

$$L_{pf} = 10\lg\left[\frac{1}{N}\sum_{i=1}^{N}10^{(L_i/10)}\right] \qquad \ldots(11)$$

where

L_{pf} is the surface sound pressure level, in decibels (reference : 20 µPa);

L_i is the mean sound pressure level, in decibels (reference : 20 µPa) for an individual microphone position or path;

N is the number of levels to be averaged.

7.8 Calculation of sound power level

The sound power level shall be calculated from the surface sound pressure level and the area of the hemisphere according to 6.10 of ISO 7779 : 1988, using the following equation :

$$L_W = L_{pf} + 10\lg\frac{S}{S_0} \qquad \ldots(12)$$

where

L_W is the sound power level, in decibels (reference : 1 pW);

L_{pf} is the surface sound pressure level, in decibels (reference : 20 µPa);

S is the area of the measurement surface, in square metres;

$S_0 = 1\ \text{m}^2$

8 Calculation of A-weighted sound power level

When the noise emissions include significant contributions from the octave bands between 125 Hz and 8 kHz, and the con-