

**ECMA**

**EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION**

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**STANDARD ECMA-108**

**MEASUREMENT  
OF HIGH-FREQUENCY NOISE  
EMITTED BY COMPUTER  
AND BUSINESS EQUIPMENT**

2nd Edition - June 1989

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## BRIEF HISTORY

In September 1981 ECMA issued Standard ECMA-74 for the Measurement of Airborne Noise Emitted by Computer and Business Equipment. This Standard was contributed to ISO/TC43, it formed the basis for International Standard ISO 7779.

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 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 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 this second edition of Standard ECMA-108 has been adapted to the final wording of ISO 9295.

Accepted as 2nd Edition of Standard ECMA-108 by the General Assembly of 29th June 1989.

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## 1. SCOPE AND FIELD OF APPLICATION

This Standard ECMA-108 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, which includes frequencies between 11,2 kHz and 22,4 kHz. They are complementary to the methods described in Standard ECMA-74. The first three methods are based on the reverberation 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.

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

### NOTE 1

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

## 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 and if the information recorded and reported is that specified in clauses 10 and 11, respectively.

## 3. REFERENCES

- |          |  |
|----------|--|
| ECMA-74  | Measurement of Airborne Noise Emitted by Computers and Business Equipment  |
| ISO 6926 | Acoustics - Determination of sound power levels of noise sources - Characterization and calibration of reference sound sources |

## 4. REQUIREMENTS FOR MEASUREMENTS IN A REVERBERATION ROOM

### 4.1 General

Three methods are described using the reverberation room technique of Standard ECMA-74. 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 4.2 to 4.6 below. Additional requirements specific to each method are given separately. For additional information on instrumentation, see ECMA-74.

#### 4.2 Instrumentation

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

##### NOTE 2

*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 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 3

*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.*

#### 4.3 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 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 4

*A test with a dummy microphone, and with the equipment under test in operation, is recommended to determine the electrical back-ground level.*

#### 4.4 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.

- Operator side facing the centre of the microphone path.
- Equipment turned clockwise by 90°.
- Equipment turned clockwise by 180°.
- 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.

#### 4.5 Calibration of Measurement System

Before the measurement of the equipment noise, the measurement set-up shall be calibrated according to 5.4.5 of ECMA-74. 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.

#### 4.6 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.

- i) The band sound pressure level with the equipment in operation.
- ii) The band sound pressure levels of the background noise (including noise produced by ancillary equipment, if any).
- iii) The band sound pressure levels of the reference sound source (if required: see 7).

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 ECMA-74.

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 equation (I).



$$L_p = 10 \log \left[ \frac{1}{N} \sum_{i=1}^N 10^{L_i/10} \right] \quad (I)$$

where  $L_i$  is the sound pressure level, in decibels (reference 20  $\mu$ Pa) for the  $i$ -th 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:

$$\Delta f = 2 f \frac{V}{C} \quad (II)$$

where

$\Delta f$  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 equation (III).

$$L_{tot} = 10 \log \sum_{i=1}^N 10^{L_i/10} \quad (III)$$

where

$L_{tot}$  is the total sound level, in decibels (reference: 20  $\mu$ Pa);

$L_i$  is the sound pressure level in an individual band, in decibels (reference: 20  $\mu$ Pa);

$N$  is the number of sideband levels to be combined.

## 5. METHOD USING MEASURED REVERBERATION TIME

### 5.1 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 4.3 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,  $\alpha$ , cannot be considered small compared to unity. Therefore, the Eyring equation (see equation IV) shall be used for the calculation of the room absorption instead of the simpler Sabine equation.

### 5.2 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 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.

### 5.3 Calculation of Room Absorption

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

$$R = \frac{S \cdot \alpha}{1 - \alpha} \quad (IV)$$

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

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;

$\alpha$  is the absorption coefficient of the room.



**5.4 Installation of Microphone and Equipment**

The microphone and the equipment under test shall be installed as described in 4.3 and 4.4, respectively.

**5.5 Measurement of Sound Pressure Level**

Before the measurement of the equipment noise, the measurement set-up shall be calibrated as described in 4.5. The average sound pressure level,  $L_p$ , shall be measured as described in 4.6. 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 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.

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

**5.6 Calculation of Sound Power Level**

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

$$L_W = L_p - 10 \log \frac{4}{R} \quad \text{(VI)}$$

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 5.5;

R is the room constant according to 5.3.

**6. METHOD USING CALCULATED AIR ABSORPTION**

**6.1 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 4.3 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 5.3 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 Appendix B.

**6.2 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 equation (VII).

$$R = \frac{8 \cdot a \cdot V}{1 - \frac{8 \cdot a \cdot V}{S}} \quad \text{(VII)}$$

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.

**6.3 Temperature and Humidity Conditions during Measurements**

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

**6.4 Installation of Microphone and Equipment**

The microphone and the equipment under test shall be installed as described in 4.3 and 4.4, respectively.

**6.5 Measurement of Sound Pressure level**

Before the equipment noise is measured, the measurement set-up shall be calibrated as described in 4.5. The average sound pressure level,  $L_p$ , shall be measured as described in 4.6. 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 of 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 - Values of the Air Absorption Coefficient

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

6.6 Calculation of Sound Power Level

The sound power level for each frequency band of interest shall be calculated from equation (VIII).

$$L_W = L_p - 10 \log \frac{4}{R} \quad \text{(VIII)}$$

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 6.5;

$R$  is the room constant calculated according to 6.2.

7. METHOD USING A REFERENCE SOUND SOURCE

7.1 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 band-width or one-twelfth octave) and the sound power levels shall be reported per unit band-width (power spectral density).

7.2 Installation of Microphone and Equipment

The microphone and the equipment under test shall be installed as described in 4.3 and 4.4, respectively.

7.3 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.

7.4 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 4.5. The average sound pressure level,  $L_p$ , shall be measured sequentially for the equipment under test and the reference sound source, as described in 4.6. 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 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.

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

7.5 Calculation of Sound Power Level

7.5.1 Equipment emitting broad-band noise

The sound power level of each one-third octave band of interest shall be calculated from equation (IX).

$$L_W = L_W(\text{RSS}) - L_p(\text{RSS}) + L_p \quad \text{(IX)}$$



where:

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

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

$L_p(RSS)$  is the average sound pressure level of the calibrated reference sound source, in decibels (reference: 20 µPa), measured according to 4.6, 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 4.6, in one-third octave bands.

### 7.5.2 Equipment emitting discrete frequency tone(s)

The sound power level shall be calculated for each frequency of interest from equation (X).

$$L_W = L_W(RSS) - L_p(RSS) + L_p + 10 \log \Delta F \quad (X)$$

where:

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

$L_W(RSS)$  is the sound power level per unit band-width of the calibrated reference sound source, for the frequency of interest, in decibels (reference: 1 pW);

$L_p(RSS)$  is the average sound pressure level of the calibrated reference sound source, in decibels (reference: 20 µPa), measured according to 4.6 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 4.6 in narrow bands;

$\Delta F$  is the bandwidth of the analyser used for the sound pressure level measurements; it is the noise bandwidth of the filter, not the bandwidth between half-power points.

#### NOTE 5

*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.*

## 8. METHOD USING A FREE FIELD OVER A REFLECTING PLANE

### 8.1 General

One method is described which uses a free field over a reflecting plane. This technique is described in 6 of ECMA-74. A semi-anechoic room shall be used for the measurements described hereafter.

#### NOTE 6

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

#### NOTE 7

*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.*

### 8.2 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  $\pm 2,0$  dB in the frequency range 11,4 kHz to 22,8 kHz.

#### NOTE 8

*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 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 9

*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.*

### 8.3 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.

- i) A rotating boom that moves the microphone(s) along five coaxial circular paths on the imaginary hemisphere. This microphone arrangement is shown in Appendix A. The traversing period should be at least 30 s. Longer periods may be suitable to reduce background noise of the drive mechanism.
- ii) A fixed microphone array as shown in Appendix A with the equipment under test mounted on a rotating turntable.



- iii) A fixed microphone array according to arrangement B.3 of Appendix B of ECMA-74 with a fixed position for the equipment under test.

NOTE 10

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 (I).

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 11

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

8.4 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 shall be the origin of the measurement hemisphere with radius r (see 8.3).

8.5 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 ECMA-74. 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.

8.6 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 8.3 shall be carried out for each frequency band within the frequency range of interest. The following data shall be obtained:

- i) the band sound pressure levels with the equipment in operation;
- ii) 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 ECMA-74.

If microphone arrangements according to 8.3 i) or ii) are used, the minimum integration time shall be 30 s. If fixed microphone locations according to 8.3. iii) are used, the minimum integration time shall be 8 s at each location.

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 8.3 i) or ii). For microphone arrangements according to 8.3 iii), 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 4.6, equation (III).

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.

8.7 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 ECMA-74, using equation (XI).

$$L_{pf} = 10 \log \left[ \frac{1}{N} \sum_{i=1}^N 10^{L_i/10} \right] \quad (XI)$$

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.

8.8 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 ECMA-74, using equation (XII).

$$L_W = L_{pf} + 10 \log \frac{S}{S_0} \quad (XII)$$

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;

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

**9. 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 contribution of the 16 kHz octave band is broad-band in character, the A-weighted sound power level shall be calculated.

The calculation shall include any band levels in the frequency range covered by the one-third octave bands with centre frequencies between 100 Hz and 20 kHz. The A-weighted sound power level,  $L_{WA}$ , shall be calculated from equation (XIII).

$$L_{WA} = 10 \log \sum_{j=1}^{24} 10^{0,1(L_j + A_j)} \quad \text{(XIII)}$$

where:

$L_{WA}$  is the A-weighted sound power level, in decibels (reference: 1 pW);

$L_j$  is the sound power level in the j-th one-third octave band;

$A_j$  is the weighting factor for the j-th one-third octave band. The values of  $A_j$  are given in Table 2.

**Table 2 - Values of the A-weighted Factor,  $A_j$ , for  $j = 1$  to 24**

j	One-third octave band centre frequency Hz	$A_j$ dB
1	100	-19,1
2	125	-16,1
3	160	-13,4
4	200	-10,9
5	250	-8,6
6	315	-6,6
7	400	-4,8
8	500	-3,2
9	630	-1,9
10	800	-0,8
11	1 000	0,0
12	1 250	0,6
13	1 600	1,0
14	2 000	1,2
15	2 500	1,3
16	3 150	1,2
17	4 000	1,0
18	5 000	0,5
19	6 300	-0,1
20	8 000	-1,1
21	10 000	-2,5
22	12 500	-4,3
23	16 000	-6,6
24	20 000	-9,3

**10. INFORMATION TO BE RECORDED**

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

**10.1 Equipment under Test**

- a) Description of the equipment under test (including principal dimensions).
- b) Operating conditions with reference to ECMA-74; 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.

**10.2 Acoustic Environment**

- e) Description of the acoustic environment, dimensions, shape and acoustical characteristics (absorption and/or reverberation time in frequency bands) of the room.
- f) Description of the microphone arrangement.
- g) Air temperature in degrees Celsius, relative humidity in percent, and barometric pressure in pascals.

**10.3 Instrumentation**

- h) Equipment used for the measurement, including name, type, serial number and manufacturer.
- i) Type and bandwidth of the frequency analyser.
- j) Frequency response of the instrumentation system.
- k) Method used for checking the calibration of the microphone(s) and other system components; date and place of calibration.
- l) Type and calibration of reference sound source; date and place of calibration.
- m) Method used for determining the average sound pressure level.

**10.4 Acoustical Data**

- n) Method used for determining sound power level.
- o) Type of noise according to Table 3.
- p) Sound power level(s) in decibels (reference: 1 pW), in one-third octave bands and/or narrow bands together with the frequency of the tone(s).
- q) A-weighted sound power level in decibels (reference: 1pW), when the noise emissions include significant contributions from the octave bands between 125 Hz and 8 kHz, and the contribution of the 16 kHz octave band is broadband in character.
- r) Date, time and place where the measurements were performed, and the name of the person performing the measurements.

**11. 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 according to Table 3.
- c) Sound power level(s) in decibels (reference: 1 pW), in one-third octave bands and/or narrow bands together with the frequency of the tone(s).

- d) A-weighted sound power level in decibels (reference: 1 pW), when the noise emissions include significant contributions from the octave bands between 125 Hz and 8 kHz, and the contribution of the 16 kHz octave band is broadband in character.
- e) Detailed description of operating conditions of the equipment under test with reference to Appendix C of ECMA-74.

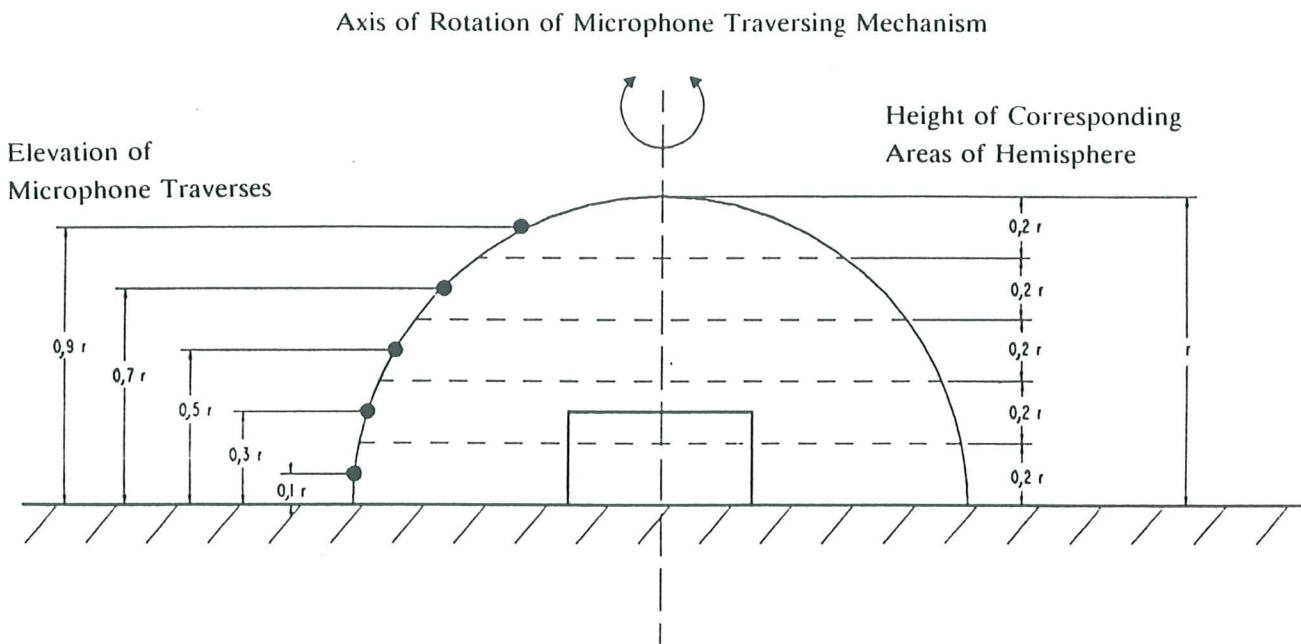
**Table 3 - Type of Noise and Determination of Sound Power Levels**

Type of noise in the frequency range of the octave bands centred at		Sound power level to be determined
125 Hz to 8 kHz ECMA-74	16 kHz ECMA-108	
Broad-band or narrow-band noise	Broad-band noise	Combined A-weighted level (125 Hz to 16 kHz) according to clause 9
Broad-band or narrow-band noise	Discrete tone	A-weighted level (125 Hz to 8 kHz) according to ECMA-74 and the level and frequency of the discrete tone according to this Standard
	Multiple tones	A-weighted level (125 Hz to 8 kHz) according to ECMA-74 and the levels and frequencies of all tones in the 16 kHz band that are within 10 dB of the highest tone level in the band
No significant noise	Discrete tone	Level and frequency of the discrete tone in the 16 kHz octave band
	Multiple tones	Levels and frequencies of all tones in the 16 kHz band that are within 10 dB of the highest tone level in the band



## APPENDIX A

### Coaxial Circular Paths in Parallel Planes for Microphone Traverses in a Free Field over a Reflecting Plane



In this arrangement either the microphones or the equipment may be rotated. Each path is associated with a zone of the hemisphere. These zones have the same height  $0,2 r$  and thus the same spherical surface area  $0,4\pi r^2$ .



## APPENDIX B

### Calculation of Air Absorption Coefficient

The air absorption coefficient,  $a$ , in nepers per metre, is calculated from the following equations (A.I) to (A.V). The frequency ( $f$ ), absolute temperature ( $T$ ), relative humidity ( $h_t$ ) and atmospheric pressure ( $p_s$ ) must be known.

#### Symbols

$T_{01}$	Triple-point isotherm temperature (= 273,16 K)
$T_0$	Reference atmosphere temperature (= 293,15 K)
$T$	Atmospheric temperature, in kelvins
$P_{s0}$	Reference atmospheric pressure (= 101,325 kPa)
$P_{sat}$	Saturation vapour pressure, in pascals
$P_s$	Atmospheric pressure, in pascals
$h$	Molar concentration of water vapour, in percent
$h_t$	Relative humidity, in percent
$f_{r,O}$	Oxygen relaxation frequency, in hertz
$f_{r,N}$	Nitrogen relaxation frequency, in hertz
$f$	Frequency, in hertz



Compute  $\lg(p_{\text{sat}}/p_{s0})$  from

$$\lg \left( \frac{p_{\text{sat}}}{p_{s0}} \right) = 10,795\ 86 \left( 1 - \frac{T_{01}}{T} \right) - 5,028\ 08 \lg \left( \frac{T}{T_{01}} \right) + 1,504\ 74 \times 10^{-4} \times [1 - 10^{-8,296\ 92 ((T/T_{01}) - 1)}] + 0,428\ 73 \times 10^{-3} \times [-1 + 10^{4,769\ 55 (1 - (T_{01}/T))}] - 2,219\ 598\ 3 \quad (\text{A.I})$$

Compute  $h$ , in percent, from

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

Compute  $f_{r,0}$  and  $f_{r,N}$ , in hertz, from

$$f_{r,0} = \frac{p_s}{p_{s0}} \left( 24 + 4,41 \times 10^4 \times h \times \frac{0,05 + h}{0,391 + h} \right) \quad (\text{A.III})$$

and

$$f_{r,N} = \frac{p_s}{p_{s0}} \left( \frac{T}{T_0} \right)^{-1/2} \left\{ 9 + 350 \times h \exp \left\{ -6,142 \left[ \left( \frac{T}{T_0} \right)^{-1/3} - 1 \right] \right\} \right\} \quad (\text{A.IV})$$

Compute the air absorption coefficient,  $a$ , in nepers per metre, from

$$a = f^2 \left[ 1,84 \times 10^{-11} \times \left( \frac{p_s}{p_{s0}} \right)^{-1} \times \left( \frac{T}{T_0} \right)^{1/2} + \left( \frac{T}{T_0} \right)^{-5/2} \times \left( \frac{1,278 \times 10^{-2} \exp(-2\ 239,1/T)}{f_{r,0} + \frac{f^2}{f_{r,0}}} + \frac{1,068 \times 10^{-1} \exp(-3\ 352/T)}{f_{r,N} + \frac{f^2}{f_{r,N}}} \right) \right] \quad (\text{A.V})$$