ECMA
EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

# STANDARD ECMA-108

# MEASUREMENT OF HIGH FREQUENCY NOISE EMITTED BY COMPUTER AND BUSINESS EQUIPMENT

December 1985

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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 forms the basis for the future International Standard ISO 7779, the present status (December 1985) of which is that of a draft international standard.

This ECMA Standard 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 emit high frequency noise, which may be broad-band noise (e.g. paper noise at high speed printing) or narrow-band noise and discrete tones (e.g. switching power supplies and video display units). The obtained levels are not frequency-weighted. The A-weighted sound power level can however be calculated from these levels, bearing in mind that A-weighting may not be the correct weighting for rating the annoyance in the 16 kHz octave band.

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## 1. SCOPE

This ECMA Standard specifies four methods for the measurement of high frequency noise emitted by computer and business equipment. The first three are based on the reverberation room technique described in Section II of Standard ECMA-74, the fourth method uses a free field over a reflecting plane described in Section III of Standard ECMA-74.

The test conditions, such as installation and operation of the equipment, shall be those specified in Standard ECMA-74.

## 2. FIELD OF APPLICATION

These four methods are suitable for the determination of high frequency noise emitted by computer and business equipment, however they can also be applied to other types of equipment.

The sound power level in the 16 kHz octave band determined according to this Standard typically is subject to a standard deviation of approximately 2,5 dB.

## 3. CONFORMANCE

A method for the measurement of high frequency noise is in conformance with this Standard if it satisfies all mandatory requirements of one of the four methods specified herein and if the information recorded and reported is that specified in clauses 7 and 8, respectively.

## 4. REFERENCES

| | |
|---|---|
| ECMA-74 | : Measurement of Airborne Noise Emitted by Computers and Business Equipment |
| ISO 354 | : Measurement of absorption coefficients in a reverberation room |
| ISO 6926 | : Characterization and calibration of reference sound sources |

## 5. REQUIREMENTS FOR MEASUREMENTS IN A REVERBERATION ROOM

### 5.1 General

Three methods are specified which use the reverberation room technique described in Section II of Standard ECMA-74. The first and the second method are usually called "direct" methods, because they use directly measured or calculated reverberation times. The third method is a so-called comparison method, using a calibrated reference sound source from which the sound power levels of the equipment are determined through 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 5.2 to 5.6. Additional requirements specific to each method are given separately.

5.2 Instrumentation

The microphone shall have a flat frequency response for randomly incident sound in the 16 kHz octave band. The tolerances should be within ± 1,5 dB in the frequency range 11,4 kHz to 22,8 kHz.

When the noise of the equipment under test is broad-band in its 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 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.

For narrow-band analysis, generally, an analyser, the bandwidth of which is equal to one-twelfth octave, is appropriate. Digital analysers using Fast Fourier Transform (FFT) or equivalent techniques may also be useful, particularly when the analyser combines narrow-band analysis and averaging.

5.3 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 may be used to reduce background noise of the drive mechanism, and to minimize modulation of any discrete tone(s) due to the moving microphone.

Care should be taken to ensure that there is no electrical pickup by the measurement instrumentation which may interfere with the sound pressure level measurement. A test with a dummy microphone, and with the equipment under test in operation, is recommended to determine the electrical background level.

5.4 Installation and Orientation of Equipment

The equipment shall be placed on the floor of the reverberation room, at least 1 m from any wall, and at least 1,5 m preferably 1,8 m, from the nearest microphone location.

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

5.5 Calibration of Measurement System

Before the measurement of the equipment noise, the measurement set-up shall be calibrated according to clause 5.4.5 of Standard ECMA-74. Calibration at a single frequency is generally sufficient, if the frequency response of the entire system including the frequency range of the 16 kHz octave band is checked periodically. Any systematic deviation in the amplifier, filter or microphone response from the flat response shall be corrected in the measured sound pressure level.

If a FFT analyser is calibrated with a single-frequency calibrator care shall be taken to have all major sideband levels included in the calibration level. Furthermore a rectangular time window shall be used for the calibration of the analyser and for the measurement of the noise of the equipment under test.

5.6 Measurement of Sound Pressure Level

The average sound pressure level in the room $L_p$ along the circular microphone path shall be measured as specified in 5.4.1 of Standard ECMA-74 in each frequency band of interest, and at the frequency of the discrete tone, respectively. 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.

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 with a different starting point.

The average value $L_p$ of the three measurements shall be calculated using the equation:

$$L_p = 10 \log \left[ \frac{1}{3} \sum_{i=1}^{3} 10^{L_i/10} \right] \qquad (1)$$

where $L_i$ is the sound pressure level in dB re 20 uPa for each individual microphone path.

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 analysis bandwidth shall be not less than:

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

where:

$\Delta f$ is the minimum value of the analysis bandwidth in Hz,
$f$ is the centre frequency of the tone in Hz,
$c$ is the speed of sound in m/s,
$v$ is the speed of the traversing microphone in m/s.

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:

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

where:

$L_{tot}$ is the total sound pressure level in dB re 20 uPa

$L_i$ is the sound pressure level in an individual band in dB re 20 uPa

N 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 may still be present. However, the microphone orientation specified in 5.3 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 absorbption 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 sufficiently small compared to 1. Therefore the Eyring equation (see equation (IV) below) 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 room with the equipment under test present shall be determined in those one-third octave bands with centre frequencies of 10 kHz to 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 room constant R for each band is calculated from the measured reverberation time as follows:

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

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

where:

S is the total surface area of the room in $m^2$,
V is the room volume in $m^3$,
T is the measured average reverberation time in s,
$\alpha$ 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 5.3 and 5.4, 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 5.5. The average sound pressure level $L_p$ shall be measured as described in 5.6. When the noise of the equipment under test is broad-band in its 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 shall be used if the frequency of the tone is to be determined and/or when multiple tones are present.

If the frequency response of the microphone, the amplifier or the filter deviates from the flat response, a correction shall be applied to the average sound pressure level.

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

### 6.6 Calculation of Sound Power Level

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

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

where:

$L_W$ is the band sound power level of the equipment in dB re 1 pW,

$L_p$ is the average band sound pressure level for the four orientations of the equipment under test in dB re 20 uPa, measured according to 6.5,

R is the room constant according to 6.3.

## 7. METHOD USING CALCULATED AIR ABSORPTION

### 7.1 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 5.3 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 6.3 and avoids the measurement of the reverberation time. The room absorption is calculated directly from the air absorption coefficient which is given in Table 1.

### 7.2 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:

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

where:

a is the air absorption coefficient in neper/m; 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 $m^2$,

V is the room volume in $m^3$.

7.3 Installation of Microphone and Equipment

The microphone and the equipment under test shall be installed as described in 1.3 and 1.4 respectively.

7.4 Measurement of Sound Pressure Level

Before the measurement of the equipment noise the measurement set-up shall be calibrated as described in 5.5. The average sound pressure level $L_p$ shall be measured as described in 5.6. When the noise of the equipment under test is broadband in its 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 shall be used to determine the 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.

If the frequency response of the microphone, the amplifier or filter deviates from the flat response, a correction shall be applied to the average sound pressure level.

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

7.5 Calculation of Sound Power Level

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

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

where:

$L_p$ is the average sound pressure level in dB re 20 uPa, measured according to 7.4, R is the room constant according to 7.2.

# 8. METHOD USING A REFERENCE SOUND SOURCE

## 8.1 Reference Sound Source, RSS

A reference sound source 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 which is at least 10 dB above the background noise level. The sound power levels of the reference sound source must be known and shall be determined by a qualified laboratory according to ISO 6926.

For the measurement of broad-band noise the calibration is to 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).

## 8.2 Installation of Microphone and Equipment

The microphone and the equipment under test shall be installed as described in 5.3 and 5.4, respectively.

## 8.3 Installation of Reference Sound Source

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

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

## 8.4 Measurement of Sound Pressure Level

Before the measurement of the noise of the equipment under test and of the reference sound source, the measurement set-up shall be calibrated as described in 5.5. The average sound pressure level $L_p$ shall be measured sequentially for the equipment under test and the reference sound source, as described in 5.6. When the noise of the equipment under test is broad-band in its 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 shall be used. The same bandwidth shall be used for the measurements of the sound pressure level of the equipment and of the reference sound source. The bandwidth and filter characteristics used shall be reported.

During a series of tests the temperature and the relative humidity of the room shall be kept constant within ± 1 °C and ± 2,5 % RH, respectively.

## 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 is calculated from the following equation:

$$L_W = L_W(RSS) - L_p(RSS) + L_p \qquad (IX)$$

where:

$L_W$ is the band sound power level of the equipment under test in dB re 1 pW,

$L_W(RSS)$ is the calibrated sound power level of the reference sound source, in the one-third octave band in dB re 1 pW,

$L_p(RSS)$ is the average sound pressure level of the reference sound source in dB re 20 uPa, measured according to 8.4 in one-third octave bands,

$L_p$ is the average sound pressure level for the four orientations of the equipment under test in dB re 20 uPa, measured according to 8.4 in one-third octave bands.

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

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

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

where:

$L_W$ is the band sound power level of the equipment under test in dB re 1 pW,

$L_W(RSS)$ is the calibrated sound power level per unit bandwidth of the reference sound source, for the frequency of interest in dB re 1 pW,

$L_p(RSS)$ is the average sound pressure level of the reference sound source in dB re 20 uPa, measured according to 8.4 in narrow-bands,

$L_p$ is the average sound pressure level for the four orientations of the test equipment in dB re 20 uPa, measured according to 8.4 in narrow-bands,

$\Delta F$ is the bandwidth of the analyser used for the sound pressure level measurements; the noise bandwidth of the filter shall be used, 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 power-spectral-density function that is a constant.*

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

## 9.1 General

One method is described which uses a free field over a reflecting plane. This technique is described in Section III of Standard ECMA-74. A laboratory-quality semi-anechoic room is considered satisfactory for the measurements described in this section. A small error may be introduced by this procedure due to interference caused by the reflecting plane.

Although air absorption plays an important role in the high frequency range, its effect is negligible for a measurement radius less than 2 m.

## 9.2 Instrumentation

The microphone should have a flat free-field frequency response for normally incident sound in the 16 kHz octave band. The tolerances should be within ± 1,5 dB in the frequency range 11,4 kHz to 22,8 kHz (see 9.6).

When the noise of the equipment under test is broad-band in its 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 shall be used to determine the frequency of the tone(s) and to determine the level and frequency of each tone when multiple tones are present.

For narrow-band analysis, generally, an analyser the bandwidth of which is equal to one-twelfth octave, is appropriate. Digital analysers using Fast Fourier Transform (FFT) or equivalent techniques may also be useful, particularly when the analyser combines narrow-band analysis and averaging.

## 9.3 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 set-ups shall be used.

i) A rotating boom that traverses along circular arcs on a hemisphere around the equipment on five coaxial paths. 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, and to minimize frequency modulation of the discrete tone(s) due to the moving microphone.

ii) A fixed microphone array as shown in Appendix A with the equipment under test mounted on a turntable.

iii) A fixed microphone array according to arrangement B.2 of Appendix B of ECMA-74 with a fixed position for the equipment under test.

Care should be taken to ensure that there is no electrical pickup by the measurement instrumentation which may interfere with the sound pressure level measurement. A test with a dummy microphone, and with the equipment under test in operation, is recommended to determine the electrical background level.

9.4 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 an imaginary hemisphere with radius r.

9.5 Calibration of Measurement System

Before the measurement of the equipment noise, the measurement set-up shall be calibrated according to clause 6.4.5 of Standard ECMA-74. Calibration at a single frequency is generally sufficient, if the frequency response of the entire system including the frequency range of the 16 kHz octave band is checked periodically. Any systematic deviation in the amplifier, filter or microphone response from the flat response shall be corrected in the measured sound pressure level.

If a FFT analyser is calibrated with a single-frequency calibrator care shall be taken to have all major sideband levels included in the calibration level. Furthermore, a rectangular time window shall be used for both calibration of the analyser and the measurement of the noise of the equipment under test.

9.6 Measurement of Sound Pressure Level

The average sound pressure level $L_p$ along the circular microphone path shall be measured as described in 5.4.1 of Standard ECMA-74 in each frequency band of interest, and at the frequency of the discrete tone, respectively. If the source is rotated, the average sound pressure level shall be determined for one revolution of the source. True integration "averaging" during a full sweep of the microphone or during a full revolution of the source is the preferred method.

If microphone arrangements according to 9.3. i) or 9.3. ii) are used the minimum integration time shall be 30 s. If fixed microphone locations according to 9.3 iii) are used the minimum integration time shall be 8 s.

When FFT analysers are used in this high frequency range, the analysis time is typically greater than the individual time window. For this reason the total measurement time shall be increased, or individual measurements should be repeated as specified in 5.6 for microphone arrangements according to 9.3 i) or 9.3 ii). For microphone arrangements according to 9.3 iii) the minimum integration time shall be increased to 30 s.

Furthermore, when using FFT or equivalent techniques for the analysis of the discrete tone(s), the levels in the side-bands shall be considered as described in 5.6, equation (III).

The bandwidth and filter characteristics used shall be reported.

If the frequency response of the microphone, the amplifier or the filter deviates from the flat response, a correction shall be applied to the average sound pressure level.

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

9.7 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 clause 6.9 of ECMA-74, using the following equation:

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

where:

$L_{pf}$ is the surface sound pressure level in dB re 20 uPa,

$L_i$ is the average sound pressure level in dB re 20 uPa for an individual microphone position or path,

N is the number of levels to be averaged.

9.8 Calculation of Sound Power Level

The sound power level is calculated from the surface sound pressure level and the area of the hemisphere according to clause 6.10 of Standard ECMA-74, using the following equation:

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

where:

$L_W$ is the sound power level in dB re 1 pW,

$L_{pf}$ is the surface sound pressure level in dB re 20 uPa,

$S$ is the area of the measurement surface in $m^2$,

$S_o$ is 1 $m^2$.

## TABLE 1

Values of the air absorption coefficient, a, in neper/m
for relative humidities of 40%, 50%, 60%
and for temperatures of 18 °C, 20 °C and 22 °C

| FREQUENCY (Hz) | AIR ABSORPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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 | 0,0221 | 0,0183 | 0,0155 | 0,0206 | 0,0169 | 0,0144 | 0,0191 | 0,0156 | 0,0134 |
| 10 500 | 0,0241 | 0,0199 | 0,0170 | 0,0224 | 0,0185 | 0,0157 | 0,0208 | 0,0171 | 0,0146 |
| 11 000 | 0,0261 | 0,0217 | 0,0185 | 0,0244 | 0,0201 | 0,0171 | 0,0227 | 0,0186 | 0,0159 |
| 11 500 | 0,0281 | 0,0235 | 0,0201 | 0,0263 | 0,0218 | 0,0186 | 0,0245 | 0,0202 | 0,0173 |
| 12 000 | 0,0302 | 0,0253 | 0,0217 | 0,0284 | 0,0236 | 0,0201 | 0,0265 | 0,0219 | 0,0187 |
| 12 500 | 0,0323 | 0,0272 | 0,0234 | 0,0304 | 0,0254 | 0,0217 | 0,0285 | 0,0236 | 0,0202 |
| 13 000 | 0,0344 | 0,0292 | 0,0251 | 0,0325 | 0,0272 | 0,0234 | 0,0305 | 0,0253 | 0,0217 |
| 13 500 | 0,0366 | 0,0312 | 0,0269 | 0,0347 | 0,0291 | 0,0250 | 0,0326 | 0,0272 | 0,0233 |
| 14 000 | 0,0387 | 0,0332 | 0,0287 | 0,0368 | 0,0311 | 0,0268 | 0,0347 | 0,0290 | 0,0249 |
| 14 500 | 0,0409 | 0,0352 | 0,0306 | 0,0390 | 0,0331 | 0,0285 | 0,0369 | 0,0309 | 0,0266 |
| 15 000 | 0,0431 | 0,0373 | 0,0325 | 0,0413 | 0,0351 | 0,0304 | 0,0391 | 0,0329 | 0,0283 |
| 15 500 | 0,0453 | 0,0395 | 0,0345 | 0,0435 | 0,0372 | 0,0322 | 0,0413 | 0,0349 | 0,0301 |
| 16 000 | 0,0475 | 0,0416 | 0,0364 | 0,0458 | 0,0393 | 0,0341 | 0,0436 | 0,0369 | 0,0319 |
| 16 500 | 0,0497 | 0,0438 | 0,0385 | 0,0481 | 0,0414 | 0,0361 | 0,0459 | 0,0390 | 0,0337 |
| 17 000 | 0,0520 | 0,0460 | 0,0405 | 0,0504 | 0,0436 | 0,0381 | 0,0482 | 0,0411 | 0,0356 |
| 17 500 | 0,0542 | 0,0482 | 0,0426 | 0,0527 | 0,0458 | 0,0401 | 0,0506 | 0,0432 | 0,0376 |
| 18 000 | 0,0564 | 0,0504 | 0,0447 | 0,0550 | 0,0481 | 0,0421 | 0,0529 | 0,0454 | 0,0395 |
| 18 500 | 0,0586 | 0,0527 | 0,0469 | 0,0573 | 0,0503 | 0,0442 | 0,0553 | 0,0476 | 0,0416 |
| 19 000 | 0,0608 | 0,0550 | 0,0491 | 0,0597 | 0,0526 | 0,0464 | 0,0577 | 0,0499 | 0,0436 |
| 19 500 | 0,0630 | 0,0573 | 0,0514 | 0,0621 | 0,0550 | 0,0486 | 0,0602 | 0,0523 | 0,0458 |
| 20 000 | 0,0652 | 0,0596 | 0,0536 | 0,0645 | 0,0573 | 0,0508 | 0,0627 | 0,0546 | 0,0479 |
| 20 500 | 0,0674 | 0,0619 | 0,0558 | 0,0668 | 0,0597 | 0,0530 | 0,0651 | 0,0569 | 0,0500 |
| 21 000 | 0,0695 | 0,0642 | 0,0581 | 0,0691 | 0,0621 | 0,0553 | 0,0676 | 0,0593 | 0,0522 |
| 21 500 | 0,0716 | 0,0665 | 0,0604 | 0,0715 | 0,0644 | 0,0575 | 0,0700 | 0,0617 | 0,0545 |
| 22 000 | 0,0738 | 0,0689 | 0,0627 | 0,0738 | 0,0668 | 0,0598 | 0,0725 | 0,0641 | 0,0567 |
| 22 400 | 0,0754 | 0,0707 | 0,0646 | 0,0756 | 0,0688 | 0,0617 | 0,0745 | 0,0661 | 0,0585 |

*NOTE*

*Other values may be calculated from Standard ANSI S1.26.*

## 10. CALCULATION OF A-WEIGHTED SOUND POWER LEVEL

From the calculated sound power levels $L_W$ in the frequency bands of interest, resp. at the frequency of the discrete tone(s), the A-weighted sound power level $L_{WA}$ may be calculated according to 5.10.3 of Standard ECMA-74. The A-weighting, Cj, for discrete frequencies in the range 10 kHz to 19 kHz is given in Table 2, for one-third octave band in Table 3.

The calculations may include any band levels in the frequency range 100 Hz to 19 kHz. If only one band level exists (e.g. for a single discrete tone), the A-weighted sound power level is calculated directly from:

$$L_{WA} = L_W + C_j \qquad (XIII)$$

TABLE 2

A-weighting
for Discrete Frequencies
10 kHz to 23 kHz

| Frequency Hz | Cj dB |
|---|---|
| 10 000 | -2,5 |
| 11 000 | -3,2 |
| 12 000 | -3,9 |
| 13 000 | -4,6 |
| 14 000 | -5,3 |
| 15 000 | -5,9 |
| 16 000 | -6,6 |
| 17 000 | -7,3 |
| 18 000 | -7,9 |
| 19 000 | -8,6 |
| 20 000 | -9,3 |
| 21 000 | -10,1 |
| 22 000 | -10,9 |
| 23 000 | -11,9 |

Linear interpolation should be used between frequencies.

TABLE 3

A-weighting
for one-third octave bands

| One-third Octave Centre Frequency Hz | Cj dB |
|---|---|
| 10 000 | -2,5 |
| 12 500 | -4,3 |
| 16 000 | -6,6 |
| 20 000 | -9,3 |

## 11. INFORMATION TO BE RECORDED

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

### 11.1 Equipment under Test

i) Description of the equipment under test (including principal dimensions).

ii) Operating conditions with reference to Standard ECMA-74; if the equipment has multiple operating modes, description of each individual mode for which measurements have been performed.

iii) Installation conditions.

iv) Location(s) of equipment in the test environment.

### 11.2 Acoustic Environment

i) Description of the acoustic environment, dimensions, shape and acoustic characteristics (absorption and/or reverberation time in frequency bands) of the room.

ii) Description of microphone arrangement.

iii) Air temperature in C, relative humidity in %, and barometric pressure in pascals.

### 11.3 Instrumentation

i) Equipment used for the measurement, including name, type, serial number and manufacturer.

ii) Type and bandwidth of frequency analyser.

iii) Frequency response of the instrumentation system.

iv) Method used for checking the calibration of the microphone(s) and other system components; date and place of calibration.

v) Type and calibration of reference sound source; date and place of calibration.

vi) Method used for determining the average sound pressure level.

### 11.4 Acoustical Data

i) Method used for determining the sound power level.

ii) The correction(s), in dB, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the passband, background noise, etc.

iii) The type of noise according to Table 4.

iv) The sound power level(s) in dB, reference 1 pW, in one-third octave bands and/or narrow-bands together with the frequency of the tone(s).

v) The A-weighted sound power level in dB, reference 1 pW, only if high-frequency broad-band noise is measured together with noise in the frequency range covered by the octave bands 125 Hz to 8 kHz.

vi) The date, time and place where the measurements were performed, and the name of the person having performed the measurements.

## 12. INFORMATION TO BE REPORTED

The report shall contain the statement that the sound power levels have been obtained in full conformance with at least one specific method described in this Standard. This report shall contain at least the following information:

- Name(s) and model number(s) of the equipment under test.
- A statement of the type of noise according to Table 4.
- Sound power level(s) $L_W$, in dB, reference 1 pW, of the tone(s) together with the frequency, or the A-weighted sound power level, $L_{WA}$, in dB, re 1 pW, if the noise is broad-band in its character.
- Detailed description of operating conditions of the equipment under test with reference to Appendix C of Standard ECMA-74.

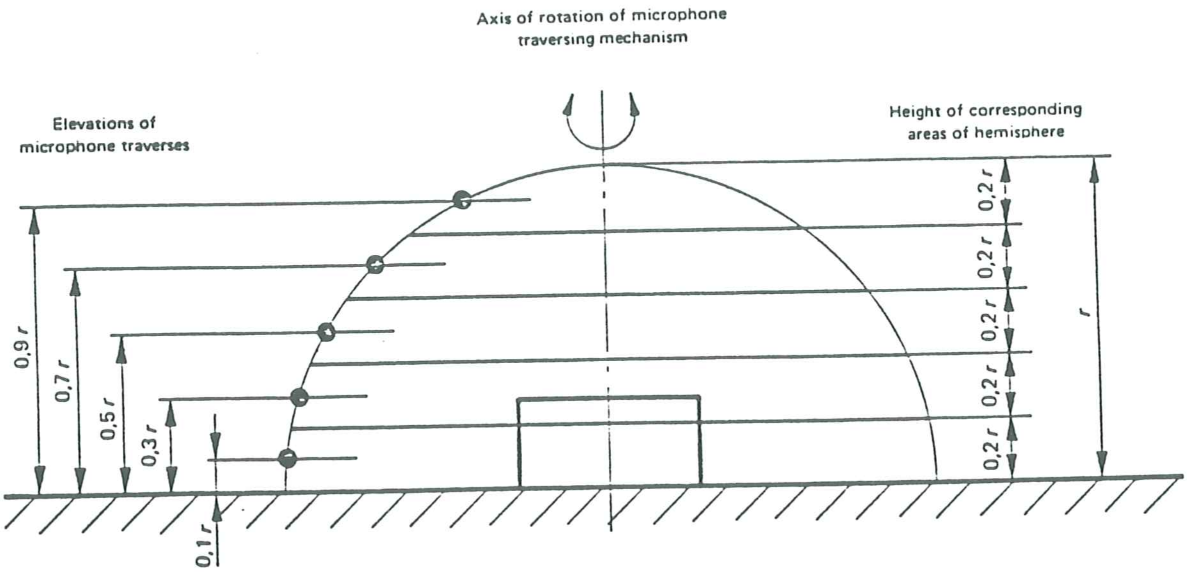
TABLE 4

Type of Noise and Reporting of Sound Power Levels

| Type of Noise in the Frequency Range of the Octave Bands centred at | | Sound Power Level to be reported |
|---|---|---|
| 125 Hz to 8 kHz ECMA-74 | 16 kHz ECMA-108 | |
| Broad-band or Narrow-band Noise | Broad-band or Narrow-band Noise | Combined A-weighted level according to ECMA-74 and ECMA-108 |
| Broad-band or Narrow-band Noise | Discrete Tone | A-weighted level according to ECMA-74 and the level and frequency of the discrete tone |
| | Multiple Tones | A-weighted level according to ECMA-74 and the level and frequency of all tones which are within 10 dB of maximum level according to ECMA-108 |
| No significant Noise | Discrete Tone | Level and frequency of Discrete Tone |
| | Multiple Tones | Level and frequency of all tones which are within 10 dB of maximum level according to ECMA-108 |

# APPENDIX A

## COAXIAL CIRCULAR PATHS IN PARALLEL PLANES FOR MICROPHONE TRAVERSES IN A FREE FIELD OVER A REFLECTING PLANE




*NOTE*

*Each path is associated with a zone of equal area.*