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AMERICAN NATIONAL STANDARD

SPECIFICATION FOR OCTAVE-BAND AND FRACTIONAL-OCTAVE-BAND ANALOG AND DIGITAL FILTERS

Accredited Standards Committee S1, Acoustics

Standards Secretariat
Acoustical Society of America
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Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

Secretariat

Acoustical Society of America

Approved 19 February 2004

American National Standards Institute, Inc.

Abstract

This standard provides performance requirements for analog, sampled-data, and digital implementations of bandpass filters that comprise a filter set or spectrum analyzer for acoustical measurements. It supersedes ANSI S1.11-1986 (R1998) *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*, and is a counterpart to International Standard IEC 61260:1995 *Electroacoustics – Octave-Band and Fractional-Octave-Band Filters*. Significant changes from ANSI S1.11-1986 have been adopted in order to conform to most of the specifications of IEC 61260:1995. This standard differs from IEC 61260:1995 in three ways: (1) the test methods of IEC 61260 clauses 5 is moved to an informative annex, (2) the term “band number,” not present in IEC 61260, is used as in ANSI S1.11-1986, (3) references to American National Standards are incorporated, and (4) minor editorial and style differences are incorporated.

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Foreword

[This foreword is for information only and is not an integral part of ANSI S1.11-2004 *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*.]

This standard replaces ANSI S1.11-1986, and is the American National Standard counterpart of International Standard IEC 61260:1995, *Electroacoustics – Octave-band and fractional-octave-band filters* including Amendment 1:2001. The technical requirements in this American National Standard are similar to those in IEC 61260.

This standard contains four informative annexes.

This standard was developed under the jurisdiction of Accredited Standards Committee S1, Acoustics, which has the following scope:

> *Standards, specifications, methods of measurement and test, and terminology, in the fields of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to safety, human tolerance, and comfort.*

At the time this standard was submitted to Accredited Standards Committee S1, Acoustics, for final approval, the membership was as follows:

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Working Group S1/WG5, Band Filter Sets, which assisted Accredited Standards Committee S1, Acoustics, in the preparation of this standard, had the following membership:

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Suggestions for improvement will be welcomed. Send suggestions for improvement to Accredited Standards Committee S1, Acoustics, in care of the ASA Standards Secretariat, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177 Telephone: +1 631 390-0215 FAX: +1 631 390-0217.

American National Standard

Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

1 Scope

1.1 This standard provides performance requirements for analog, sampled-data, and digital implementations of bandpass filters that comprise a filter set or spectrum analyzer. The extent of the passband region of a filter's relative attenuation characteristic is a constant percentage of the midband frequency for all filters of a given bandwidth. An instrument complying with the requirements of this standard may contain any number of bandpass filters covering any desired frequency range. Methods for testing the performance of filters are given in an informative annex.

1.2 Performance requirements are provided for three filter classes designated class 0, class 1, and class 2. Allowed tolerance limits increase as the class number increases.

1.3 Bandpass filters conforming with the performance requirements of this standard may be part of various measurement systems or may be an integral component of a specific instrument and shall operate in real time. Performance requirements apply to any method that is selected by the manufacturer to implement the design of the filters.

1.4 Instruments conforming with the requirements of this standard are capable of providing frequency-band-filtered spectral information for a wide variety of signals, for example, time-varying, intermittent, and steady; broadband and discrete frequency; and long and short durations. For applications involving transient signals, different realizations of filters meeting the requirements of this standard may give different results.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

2.1 American National Standards

ANSI S1.1-1994 (R1999), *American National Standard Acoustical Terminology*.

ANSI S1.4-1983 (R2001), *American National Standard Specification for Sound Level Meters* with Amendment ANSI S1.4A-1985 (R2001).

ANSI S1.6-1984 (R2001), *American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements*.

ANSI S1.14-1988 (R2003), *American National Standard Recommendations for Specifying and Testing the Susceptibility of Acoustical Instruments to Radio-Frequency Electromagnetic Fields, 25 MHz to 1 GHz.*

ANSI S1.43-1997 (R2002), *American National Standard Specifications for Integrating-Averaging Sound Level Meters*.

2.2 International Standards

IEC 60050(801):1994, *International Electrotechnical Vocabulary* – Chapter 801: *Acoustics and electroacoustics*.

ISO Publication, *International vocabulary of basic and general terms in metrology*, ISBN 92-67-01075-1, 1993.

NOTE – The above reference is specified for compatibility with IEC 61260.

3 Definitions

For the purpose of this standard, the definitions contained in IEC 61000-4-2, IEC 61000-4-3, IEC 61000-6-1, IEC 61000-6-2 and CISPR 61000-6-3 as well as the following definitions apply.

NOTE – For definitions of additional terms in this standard, reference should be made to ANSI S1.1, IEC 60050(801), and the OIML *Vocabulary of Legal Metrology*.

3.1 bandpass filter. Filter with a single transmission band (or passband with small relative attenuation) extending from a lower bandedge frequency greater than zero to a finite upper bandedge frequency.

3.2 octave ratio. Nominal frequency ratio of 2:1; general symbol G. Two options, designated base-ten and base-two, for determining an octave-band, or fractional-octave-band, frequency ratio are permitted. The base-ten system is preferred. For base-ten systems,

$$G_{10} = 10^{3/10} \qquad (1)$$

For base-two systems,

$$G_2 = 2 \qquad (2)$$

3.3 bandwidth designator. Reciprocal of a positive integer, including 1, to designate the fraction of an octave band; symbol $1/b$.

3.4 reference frequency. Frequency of 1000 Hz, exactly; symbol f_r.

3.5 exact midband frequency. In hertz, a frequency that has a specified relationship to the reference frequency such that the ratio of the exact midband frequencies of any two contiguous bandpass filters is the same for all filters in a filter set of a specified bandwidth; symbol f_m. When the denominator of the bandwidth designator is an odd number, exact midband frequencies of any filter in a set of filters are determined from

$$f_m = (G^{(x-30)/b})(f_r) \qquad [b \text{ odd}] \qquad (3)$$

and when the denominator of the bandwidth designator is an even number, exact midband frequencies of any filter in a set of filters are determined from

$$f_m = (G^{(2x-59)/(2b)})(f_r) \qquad [b \text{ even}] \qquad (4)$$

where x is any integer, positive, negative, or zero.

NOTES

1 Exact midband frequencies determined from equation (3) or (4) permit the output of narrow-fractional-octave-band filters to be combined to yield the band level of a filter of wider-bandwidth with a corresponding exact midband frequency and corresponding bandedge frequencies.

2 With the base-ten system, midband frequencies included within any 10:1 frequency range are the same as within any other 10:1 frequency range except for the position of the decimal sign. With the base-two system, midband frequencies are unique and do not repeat.

3 As examples, for one-third-octave-band filters, the exact midband frequency for the band with a nominal midband frequency of 5000 Hz is, to three decimal places, 5,011.872 Hz by the base-ten system and 5,039.684 Hz by the base-two system, or a difference of approximately 0.6%. At a nominal midband frequency of 50,000 Hz, the exact midband frequency is, to three decimal places, 50,118.723 Hz by the base-ten system and 50,796.834 Hz by the base-two system, or an approximate difference of 1.4%.

4 When the denominator of the bandwidth designator is an odd number, one of the filters in a complete filter set may have a midband frequency of 1000 Hz. When the denominator of the bandwidth designator is an even number, the bandedge frequency of one adjacent pair of filters in a complete filter set may be at 1000 Hz and therefore none of the filters will have a midband frequency of 1000 Hz.

5 Exact midband frequencies for octave-band and one-third-octave-band filters are given in table A1 for the usual range of audio frequencies.

6 When the bandwidth designator $1/b$ is 1/3, the quantity x in equation (3) is known as the band number.

3.6 nominal midband frequencies. In hertz, rounded midband frequencies for the designation of bandpass filters.

3.7 bandedge fequencies. In hertz, frequencies of the lower and upper edges of the passband of a bandpass filter such that the exact midband frequency is the geometric mean of the lower and upper bandedge frequencies; symbols f_1 and f_2, respectively. Bandedge frequencies are determined from

$$f_1 = (G^{-1/(2b)})(f_m) \quad (5)$$

and

$$f_2 = (G^{+1/(2b)})(f_m) \quad (6)$$

where

G represents an octave frequency ratio calculated according to equation (1) for base-ten systems or (2) for base-two systems;

f_m is an exact midband frequency determined from equation (3) or (4) and $\sqrt{f_1 f_2} = f_m$.

3.8 normalized frequency. For a bandpass filter, ratio of frequency to the exact midband frequency; symbol f/f_m .

3.9 filter bandwidth. In hertz, for a given filter, upper bandedge frequency f_2 minus the corresponding lower bandedge frequency f_1 calculated from equations (5) and (6).

3.10 octave-band filter. Bandpass filter for which the nominal ratio of upper bandedge frequency to lower bandedge frequency is two.

3.11 fractional-octave-band filter. Bandpass filter for which the ratio of upper bandedge frequency f_2 to lower bandedge frequency f_1 is an octave ratio raised to an exponent equal to the applicable bandwidth designator.

NOTE – In symbols, a bandedge frequency ratio is $f_2/f_1 = G^{1/b}$.

3.12 filter attenuation. In decibels, for a bandpass filter, at any frequency, the level of the time-mean-square input signal minus the level of the indicated time-mean-square output signal, with both signal levels relative to the same reference quantity; symbol A.

NOTE – In symbols, a time-mean-square input signal level L_{in}, in decibels, is represented by

$$L_{in} = 10\lg\left(\left[\left(1/T\right)\int_0^T V_{in}^2(t)dt\right]\Big/V_0^2\right) \text{ dB} \quad (7)$$

where

$V_{in}(t)$ is the instantaneous input signal as a function of time t;

T is the elapsed time for integration;

V_0 is an appropriate reference quantity such as 20 μV.

A corresponding expression applies for the level of the time-mean-square output signal.

3.13 reference attenuation. In decibels, for all bandpass filters in an instrument, nominal filter attenuation in the passband as specified by the manufacturer for determining relative attenuation; symbol A_{ref} .

3.14 relative attenuation. In decibels, for a bandpass filter, at any frequency, filter attenuation minus the reference attenuation; symbol ΔA.

NOTE – At any normalized frequency f/f_m , relative attenuation $\Delta A(f/f_m)$, in decibels, is determined from

$$\Delta A(f/f_m) = A(f/f_m) - A_{ref} \quad (8)$$

where

$A(f/f_m)$ is the filter attenuation at normalized frequency f/f_m ;

A_{ref} is the reference attenuation.

Exact midband frequencies f_m are calculated from equation (3) or (4).

3.15 normalized effective bandwidth. For constant-amplitude sinusoidal electrical input signals, integral over normalized frequency of the ratio of the time-mean-square signal indicated by the readout device at the output of the filter set to the time-mean-square input signal with the integral normalized by multiplying by a constant equal to $10^{0.1\,A_{ref}}$ where A_{ref} is the reference attenuation, in decibels; symbol B_e .

NOTE – The analytical expression for normalized effective bandwidth is given in 4.5.2.

3.16 normalized reference bandwidth. For a bandpass filter, ratio of filter bandwidth to the exact midband frequency; symbol B_r. Normalized reference bandwidth B_r is determined from

$$B_r = (f_2 - f_1)/f_m = [G^{+1/(2b)} - G^{-1/(2b)}] \quad (9)$$

3.17 filter integrated response. In decibels, ten times the logarithm to the base ten of the ratio of the normalized effective bandwidth of a filter to the normalized reference bandwidth; symbol ΔB.

NOTE – The analytical expression for ΔB is given in 4.5.1.

3.18 reference level range. In decibels, one of the available level ranges specified by the manufacturer for testing electrical performance characteristics.

3.19 reference input signal level. In decibels, level of the input signal, specified by the manufacturer, on the reference level range.

3.20 level difference. In decibels, for a bandpass filter on any level range, output signal level minus the input signal level plus the nominal attenuation of the level range control, if applicable.

3.21 reference level difference. In decibels, on the reference level range, level difference for an input signal at the applicable reference input signal level at the midband frequency.

3.22 level linearity error. In decibels, on any level range, a level difference at the midband frequency minus the reference level difference.

3.23 linear operating range. In decibels, for a stated filter bandwidth and a stated level range, the extent of steady sinusoidal input signal levels over which level linearity errors are maintained within specified tolerance limits from a lower boundary to an upper boundary.

3.24 level range control. A device for adjusting the sensitivity of an instrument in response to changes in the level of the input signal in order to maintain the overall operation of the instrument within the linear operating range.

3.25 measurement range. In decibels, for any nominal midband frequency, the upper boundary of the input signal level for the linear operating range on the least-sensitive level range minus the lower boundary of the input signal level for the linear operating range on the most-sensitive level range.

3.26 analog filter. Filter that operates continuously on the input signal to produce a filtered output.

3.27 sampled-data filter. Computational process that operates on samples of the input signal to produce a filtered output.

3.28 digital filter. Subset of sampled-data filters that operates on digitized samples of input data.

3.29 real-time operation. An operational mode or capability of a sampled-data filter system to produce bandpass-filtered output signal levels and for which, on average, the computing associated with each sampling interval is completed in a time period less than or equal to the sampling interval such that all input data are processed within the sampling interval and all samples of an input signal contribute with equal weight to the resulting filtered output signal levels.

3.30 aliased frequency components. Spurious frequency components in the output signal from a sampled-data bandpass filter that result when a time-varying, but continuous, input signal is sampled at a rate that is too low relative to the highest frequency component of the input signal.

3.31 antialias filter. Low-pass filter to reduce the contribution of aliased frequency components in the output to an insignificant level.

3.32 reference orientation (of a bandpass filter). Orientation of a bandpass filter with respect to the principal direction of an emitter or receiver of radio-frequency fields.

according to this standard and which specifies connection to a public power supply system for the normal mode of operation, requiring no external connections to other apparatus to operate the instrument.

4 Performance requirements

4.1 General

Electrical response characteristics specified in this standard for octave-band and fractional-octave-band filters apply under the reference environmental conditions of 4.13.

Any filter design realization, with a base-ten or a base-two octave frequency ratio, may be utilized providing the resulting instrument conforms with all applicable requirements of this standard.

4.2 Nominal midband frequencies

Octave-band and fractional-octave-band filters shall be identified, or labeled, by nominal midband frequencies that are suitably rounded values of exact midband frequencies. Annex A provides exact and nominal midband frequencies for octave-band and one-third-octave-band filters. A procedure is described for determining the nominal midband frequencies for fractional-octave-band filters with bandwidth designators from 1/4 to 1/24.

4.3 Reference attenuation

The manufacturer shall specify the reference attenuation in the passband. The reference attenuation shall be the same for all filters in a set of filters.

4.4 Relative attenuation

4.4.1 For octave-band filters of class 0, 1, or 2, the relative attenuation of any filter shall be within the limits in table 1 for the minimum and maximum relative attenuations at the specified values of octave-band normalized frequency $f/f_\mathrm{m} = \Omega$.

4.4.2 For a fractional-octave-band filter with bandwidth designator $1/b$, the high-frequency fractional-octave-band normalized frequency $\Omega_{\mathrm{h}(1/b)}$, corresponding to a finite relative attenuation limit for the accuracy class shall be calculated, for $\Omega \geq 1$, from

$$\Omega_{\mathrm{h}(1/b)} = 1 + [(G^{1/(2b)} - 1)/(G^{1/2} - 1)](\Omega - 1) \quad (10)$$

For $\Omega < 1$, the low-frequency fractional-octave-band normalized frequency $\Omega_{\mathrm{l}(1/b)}$ shall be calculated from

$$\Omega_{\mathrm{l}(1/b)} = 1/\Omega_{\mathrm{h}(1/b)} \quad (11)$$

for the same limit on relative attenuation.

NOTE – Annex B provides an example calculation of the normalized frequencies at the breakpoints for the limits on minimum and maximum relative attenuation for one-third-octave-band filters.

4.4.3 At normalized frequencies Ω_a and Ω_b given in table 1 for octave-band filters, or between comparable normalized fractional-octave-band frequencies calculated according to equation (10) or (11) for fractional-octave-band filters, the limit for relative attenuation ΔA_x at normalized frequency Ω_x shall be determined from the linear interpolation relation

$$\Delta A_\mathrm{x} = \Delta A_\mathrm{a} + [\Delta A_\mathrm{b} - \Delta A_\mathrm{a}][\lg(\Omega_\mathrm{x}/\Omega_\mathrm{a})/\lg(\Omega_\mathrm{b}/\Omega_\mathrm{a})] \quad (12)$$

where

ΔA_a is a relative attenuation limit at normalized frequency Ω_a ;

ΔA_b is a relative attenuation limit at normalized frequency Ω_b .

4.4.4 Figure 1 illustrates the limits on minimum and maximum relative attenuation for an octave-band filter. The figure also shows the discontinuous changes in minimum and maximum relative attenuation at the bandedge frequencies and the linear variation of relative attenuation limits between the breakpoint normalized frequencies of table 1.

4.5 Filter integrated response

4.5.1 For a bandpass filter, filter integrated response ΔB, in decibels, shall be determined from

$$\Delta B = 10 \lg(B_\mathrm{e}/B_\mathrm{r}) \text{ dB} \quad (13)$$

where

B_e is the normalized effective bandwidth;

B_r is the normalized reference bandwidth from equation (9) for the same midband frequency.

4.5.2 For any filter of exact midband frequency f_m , normalized effective bandwidth is represented by

$$B_\mathrm{e} = \int_0^\infty 10^{-0.1\Delta A(f/f_\mathrm{m})} d(f/f_\mathrm{m}) \quad (14)$$

where $\Delta A(f/f_{m.})$ is the continuous relative-attenuation filter response, in decibels. In practice, the integral in equation (14) is evaluated numerically.

4.5.3 For each bandpass filter in an instrument, the filter integrated response shall not exceed ±0.15 dB, ±0.3 dB, and ±0.5 dB for classes 0, 1 and 2 instruments, respectively.

4.6 Linear operating range

4.6.1 For all filter bandwidths, and for the flat frequency response if provided, and for each available level range, the level linearity errors on the linear operating range shall not exceed ±0.3 dB, ±0.4 dB, and ±0.5 dB respectively over linear operating ranges of at least 60 dB, 50 dB, and 40 dB for classes 0, 1, and 2 filters, respectively.

4.6.2 Level ranges, if more than one is provided, shall overlap such that the linear operating ranges overlap by at least 40 dB for class 0 and class 1 filters and at least 30 dB for class 2 filters.

4.6.3 For filters with more than one level range, a reduced linear operating range is allowed on the most sensitive range, provided it is not the reference level range.

4.6.4 For filters where a display is an integral component, or when the filter output is transferred to an external display or to another system, and the range of the display is greater than the linear operating range, the manufacturer shall specify the tolerance limits on level linearity that are maintained outside the linear operating range.

4.7 Real-time operation

The manufacturer shall state the bandwidth designators and corresponding frequency ranges for which the level of the output signal in response to a constant-amplitude sinusoidal input signal, the logarithm of the frequency of which is varied at a constant rate, is within ±0.3 dB of the theoretical output signal level for class 0 and class 1 instruments, and within ±0.5 dB for class 2 instruments.

NOTES

1 For a given swept-frequency sinusoidal input signal, the theoretical time-average output signal level, L_c, in decibels, that would be indicated at the output, with a relative attenuation equal to the reference attenuation of the actual filter and infinite attenuation outside the bandedge frequencies, is

$$L_c = L_{in} - A_{ref} + 10\,\lg\{(T_{sweep}/T_{avg})[\lg(f_2/f_1)/\lg(f_{end}/f_{start})]\}\ \text{dB} \tag{15}$$

where

L_{in} is the time-average signal level of the constant-amplitude input signal;

T_{sweep} is the time required to sweep at a logarithmic rate from the starting frequency f_{start} to the ending frequency f_{end};

f_1 and f_2 are the bandedge frequencies; and

T_{avg} is the averaging time selected for measurement of the output signal level.

2 In equation (15), $\lg(f_2/f_1)$ equals $3/(10b)$ for base-ten systems and $(1/b)\lg(2)$ for base-two systems.

4.8 Antialias filters

The manufacturer shall include antialias filters, analogue and digital as appropriate, in a sampled-data or digital filter system. Antialias filters shall minimize interference between an input signal and the sampling process that would create aliased frequency components of the input signal and cause the relative attenuation response of a filter to exceed the greatest value of the applicable minimum limits of table 1.

4.9 Summation of output signals

For a sinusoidal input signal at any frequency between two consecutive octave or fractional-octave midband frequencies, the difference between (a) the level of the input signal minus the reference attenuation and (b) the level of the sum of the time-mean-square output signals from the three filters with the least relative attenuation shall not exceed ±1.0 dB; +1.0 dB, –2.0 dB; and +2.0 dB, –4.0 dB for class 0, 1, and 2 instruments, respectively.

4.10 FLAT frequency response

If an instrument has a range of frequency-independent (i.e., "FLAT") transmission, the manufacturer shall state a range of frequencies over which the relative attenuation is within ± 0.15 dB, ± 0.3 dB, and ± 0.5 dB of the relative attenuation at the reference frequency for class 0, 1, and 2 instruments, respectively. The reference attenuation for measurements of relative attenuation with FLAT frequency response is the same as that for the relative attenuation of a bandpass filter.

4.11 Maximum input signal

The manufacturer shall state the maximum root-mean-square voltage of the sinusoidal input signal on each level range for which every filter in the instrument confirms to the requirements of this standard.

4.12 Terminating impedances

If applicable, the manufacturer shall state the input and output terminating impedances necessary to ensure proper operation of the instrument.

4.13 Reference environmental conditions

Reference environmental conditions include an ambient air temperature of 23 ^{o}C, a relative humidity of 50%, and an atmospheric pressure of 101.325 kPa.

Table 1. Limits on relative attenuation for octave-band filters.

Breakpoint normalized frequency $f/f_m = \Omega$	Minimum; maximum attenuation limits, in decibels — Filter class 0	1	2
G^{0}	–0.15; +0.15	–0.3; +0.3	–0.5; +0.5
$G^{\pm 1/8}$	–0.15; +0.2	–0.3; +0.4	–0.5; +0.6
$G^{\pm 1/4}$	–0.15; +0.4	–0.3; +0.6	–0.5; +0.8
$G^{\pm 3/8}$	–0.15; +1.1	–0.3; +1.3	–0.5; +1.6
$\lim_{e\to 0} G^{\pm[(1/2)-\lvert e\rvert]}$	–0.15; +4.5	–0.3; +5.0	–0.5; +5.5
$G^{\pm 1/2}$ a)	+2.3; +4.5	+2.0; +5.0	+1.6; +5.5
$G^{\pm 1}$	+18.0; +∞	+17.5; +∞	+16.5; +∞
$G^{\pm 2}$	+42.5; +∞	+42; +∞	+41; +∞
$G^{\pm 3}$	+62; +∞	+61; +∞	+55; +∞
$\geq G^{+4}$ / $\leq G^{-4}$	+75; +∞	+70; +∞	+60; +∞

a) At frequencies less than the lower bandedge frequency and greater than the upper bandedge frequency, the limit on maximum relative attenuation is +∞; see figure 1.

4.14 Sensitivity to various environments

4.14.1 Ambient air temperature. Over the minimum range of ambient temperature from 0°C to +50 °C, the relative attenuation for any filter available in the instrument and at the nominal midband frequency shall not deviate from the relative attenuation at the same frequency under reference environmental conditions by more than ±0.15 dB, ±0.3 dB, and ±0.5 dB for class 0, 1, and 2 instruments, respectively.

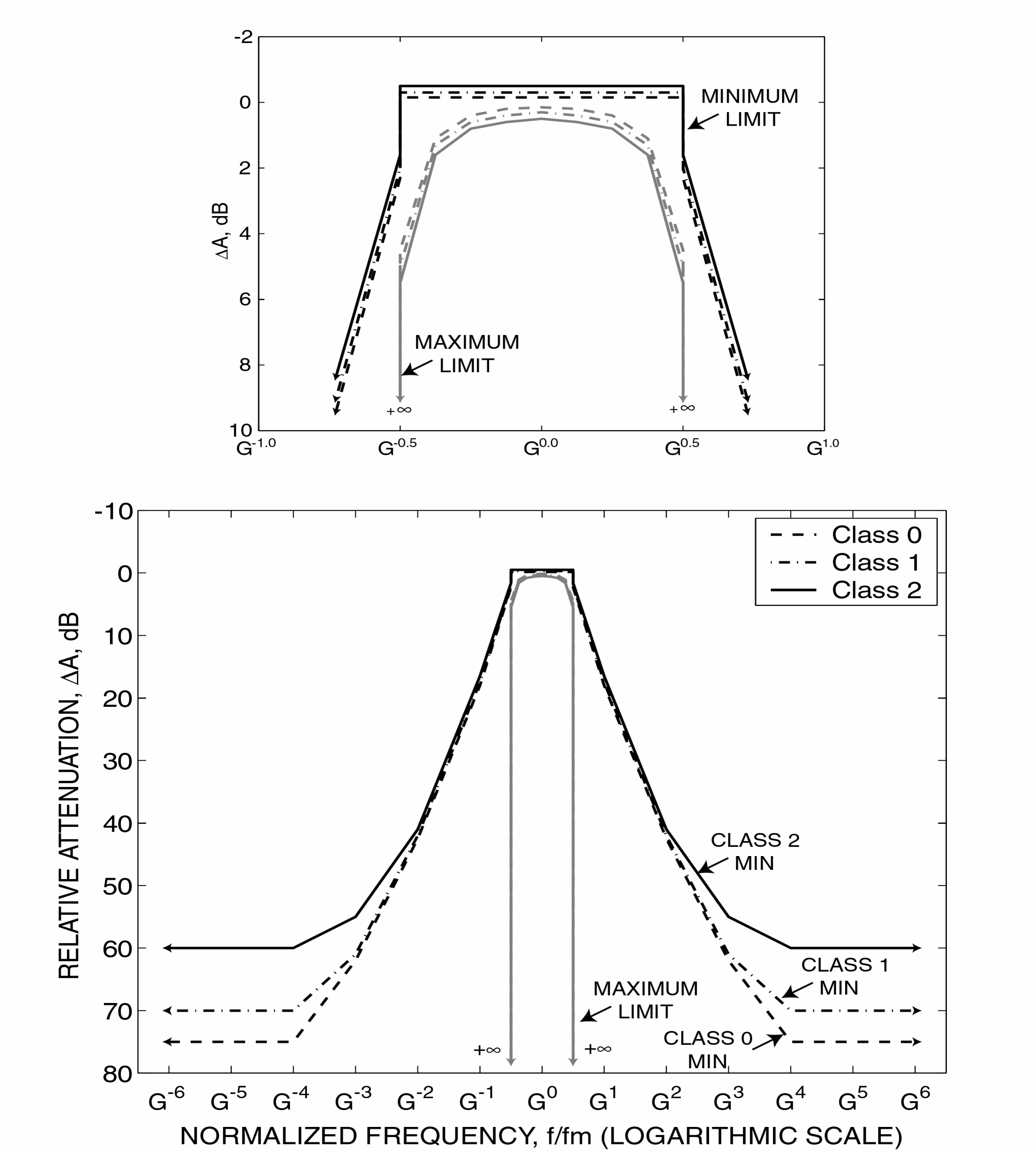

Figure 1. Illustration of minimum and maximum limits on relative attenuation for class 0, 1, and 2 octave-band filters.

4.14.2 Relative humidity. The manufacturer shall state the range of relative humidity and corresponding air temperature over which the instrument can operate continuously. After a 24 the humid atmosphere at a relative humidity of 75%, and at an ambient air temperature of +40 °C and without condensation on internal components of the instrument under test, the relative attenuation at the nominal midband frequency for any filter available in the instrument shall not deviate from the relative attenuation at the same frequency under reference environmental conditions by more than ±0.15 dB, ±0.3 dB, and ±0.5 dB for class 0, 1, and 2 instruments, respectively.

4.14.3 Alternating magnetic fields. The influence of magnetic fields alternating at 50 Hz and 60 Hz (and at harmonics of the fundamental frequency) on the operation of a filter set shall be reduced as far as practicable.

4.14.4 Electrostatic discharges. The influence of electrostatic discharge on the operation of a filter set shall be reduced as far as practicable.

4.15.5 Radio-frequency electromagnetic fields. The influence of radio-frequency electromagnetic fields on the operation of a filter set shall be as far as practicable.

4.15 Power supply check

For instruments that require a battery power supply, the manufacturer shall provide a suitable means to check that the power supply is adequate, at the time of checking, to operate the instrument according to all requirements of this standard.

5 Performance verification

Recommendations for verification of the electrical performance characteristics required by this standard are given in Annex C. Recommended test methods are given in Annex D.

6 Instrument marking

A filter set that conforms to all requirements of this standard shall be marked "YYY- band filter, class X, ANSI S1.11-2004" where YYY is the bandwidth, for example octave, and X is 0, 1, or 2, as appropriate. The filter set shall also be marked with the name of the manufacturer, the model, and serial number, if practical.

7 Instruction manual

The instruction manual for a filter set shall include at least the information listed below:

a) a statement that all filters of all nominal filter bandwidths available in each analysis channel of a filter (if more than one channel is available) conform to all performance requirements of this standard within the tolerance limits for a performance class;

b) a description of the analytical method that was selected to implement the design of the filters;

c) for digital and sampled-data filters, the sampling frequency or frequencies applicable to the various filters;

d) for each analysis channel available, a list of the nominal midband frequencies for all filters of each available filter bandwidth, in accordance with Annex A;

e) a statement of the system, base-ten or base-two, selected to determine the octave frequency ratio;

f) the reference level range;

g) the reference input signal level;

h) the reference attenuation;

i) the linear operating range and the linearity tolerance limits (maximum level linearity error) of output signal levels displayed outside the linear operating range;

j) for each level range, recommendations on operation of the instrument to ensure that measurements are made within the linear operating range;

k) for each nominal filter bandwidth available, the frequency range for real-time operation and other information pertinent to real-time spectral analyses of transient and time-varying signals;

l) if available, the frequency range of nominally FLAT frequency response;

m) the maximum root-mean-square voltage of a sinusoidal input signal at any frequency in the range of the instrument and for each level range;

n) if required, the real and reactive components of the terminating impedances that should be placed at the input and output of the instrument;

o) the temperature limits and corresponding exposure times which, if exceeded, will result in permanent damage to the instrument;

p) limitations on the use of the instrument in proximity to a source of alternating magnetic fields;

q) limitations on operation of the instrument in proximity to sources of electrostatic discharge, especially under low humidity conditions;

r) limitations on operation of the instrument in proximity to sources of radio-frequency electromagnetic fields;

s) if battery powered, the recommended means to check that electrical power supplied by batteries is sufficient to operate the instrument within all applicable tolerance limits at the time of checking;

t) if the filter is intended to be operated in conjunction with a sound level meter or equivalent instrument, the specific instrument shall be identified;

u) the maximum time needed, after turning on a filter set which had been off sufficiently long at the prevailing ambient air temperature to reach thermal equilibrium, before the instrument may be used to measure filtered output signal levels that conform with the requirements of this standard for all applicable ambient air temperatures;

v) any additional information required to conduct tests to verify that the filter set conforms to the performance requirements of this standard within the applicable tolerance limits or to use the instrument to obtain bandpass-filtered output signal levels within the accuracy tolerance limits for the class.

w) the short circuit that may be applied to the input of the bandpass filter;

x) approved cables and accessories;

y) the configuration for the normal mode of operation;

z) any specified degradation in performance or loss of functionality following the application of electrostatic discharges;

aa) the configuration for the reference orientation;

bb) the setting and configuration for greatest radio-frequency emissions; and

cc) the mode of operation and connecting devices that produce minimum immunity to power- and radio-frequency fields.

Annex A
(informative)

Midband frequencies

A.1 Nominal midband frequencies for bandwidth designators 1/1 and 1/3

Exact and nominal midband frequencies for one-third-octave-band and octave-band filters are given in table A1.

A.2 Nominal midband frequencies for bandwidth designators 1/4 to 1/24 inclusive

For either octave frequency ratio from 3.2, nominal midband frequencies shall be determined by rounding the corresponding exact midband frequencies obtained from application of equation (3) or equation (4), as appropriate, using the base-ten version of the octave frequency ratio in equation (1). When the most significant digit (that is, left-most) of an exact midband frequency is between 1 and 4 inclusive, the nominal midband frequency is calculated by rounding to the first three significant digits. When the most significant digit of an exact midband frequency is between 5 and 9 inclusive, the nominal midband frequency is calculated by rounding to two significant digits.

Example: for the base-ten system with $G = 10^{3/10}$, $1/b$ = 1/24 and x = –81, the exact midband frequency from equation (4) is 41.567 Hz to five figures. The corresponding nominal midband frequency is 41.6 Hz. For x = +105, the exact midband frequency is 8,785.2 Hz to five figures and the corresponding nominal midband frequency is 8800 Hz.

A.3 Nominal midband frequencies for bandwidth designators smaller than 1/24

When the denominator b of a bandwidth designator is greater than 24, the procedure of A.2 is used with the exception that the number of significant digits is increased to provide unique values for the nominal midband frequencies in any 1:10 frequency ratio.

Table A1. Midband frequencies for one-third-octave-band and octave-band filters in the audio range.

Band number x	Base-ten exact f_m $(10^{x/10})$, Hz	Base-two exact f_m $(2^{(x-30)/3})(1000)$, Hz	Nominal midband frequency, Hz	Octave
14	25.119	24.803	25	
15	31.623	31.250†	31.5	*
16	39.811	39.373	40	
17	50.119	49.606	50	
18	63.096	62.500†	63	*
19	79.433	78.745	80	
20	100.00†	99.213	100	
21	125.89	125.00†	125	*
22	158.49	157.49	160	
23	199.53	198.43	200	
24	251.19	250.00†	250	*
25	316.23	314.98	315	
26	398.11	396.85	400	
27	501.19	500.00†	500	*
28	630.96	629.96	630	
29	794.33	793.70	800	
30	1,000.0†	1,000.0†	1 000	*
31	1,258.9	1,259.9	1 250	
32	1,584.9	1,587.4	1 600	
33	1,995.3	2,000.0†	2 000	*
34	2,511.9	2,519.8	2 500	
35	3,162.3	3,174.8	3 150	
36	3,981.1	4,000.0†	4 000	*
37	5,011.9	5,039.7	5 000	
38	6,309.6	6,349.6	6 300	
39	7,943.3	8,000.0†	8 000	*
40	10,000†	10,079	10 000	
41	12,589	12,699	12 500	
42	15,849	16,000†	16 000	*
43	19,953	20,159	20 000	

NOTES

1 Exact midband frequencies are calculated from equation (3) to five significant figures except for the exact values marked by †.

2 See ANSI S1.6 for other nominal midband frequencies of one-third-octave and octave-band filters.

3 Table rows relevant for octave-band filters are designated by an asterisk * in the octave column.

Annex B
(informative)

Normalized frequencies at breakpoints of limits on minimum and maximum relative attenuation for one-third-octave-band filters

B.1 This annex provides an example calculation of the normalized frequencies for the limits on minimum and maximum relative attenuation for a one-third-octave-band filter, i.e., for $1/b$ = 1/3.

B.2 For the initial calculation, let $\Omega = G^{1/8}$. From equation (10), the high-frequency breakpoint is found from the general relationship:

$$\Omega_{h(1/3)} = 1 + [(G^{1/6} - 1)/(G^{1/2} - 1)](G^{1/8} - 1)$$

B.3 For base-ten systems with $G = 10^{3/10}$,

$$\Omega_{h(1/3)} = 1 + [(10^{1/20} - 1)/(10^{3/20} - 1)](10^{3/80} - 1)$$
$$\approx 1.026{,}67$$

B.4 For base-two systems with $G = 2$,

$$\Omega_{h(1/3)} = 1 + [(2^{1/6} - 1)/(2^{1/2} - 1)](2^{1/8} - 1)$$
$$\approx 1.026{,}76$$

B.5 From equation (11), the corresponding low-frequency breakpoints are

$$\Omega_{l(1/3)} \approx 0.974{,}02 \text{ for base-ten}$$

and

$$\Omega_{l(1/3)} \approx 0.973{,}94 \text{ for base-two}$$

B.6 Application of equations (10) and (11) for the octave-band breakpoint frequencies in table 1 yielded the normalized frequencies in table B1 for one-third-octave-band filters.

Table B1. Limits on relative attenuation for one-third-octave-band filters.

Breakpoint normalized frequency, f/f_m for Ω_h and Ω_l		Minimum; maximum attenuation limits, dB		
		Filter class		
base-ten	base-two	0	1	2
1.000,00	1.000,00	–0.15; +0.15	–0.3; +0.3	–0.5; +0.5
1.026,67 ----------- 0.974,02	1.026,76 ----------- 0.973,94	–0.15; +0.2	–0.3; +0.4	–0.5; +0.6
1.055,75 ----------- 0.947,19	1.055,94 ----------- 0.947,02	–0.15; +0.4	–0.3; +0.6	–0.5; +0.8
1.087,46 ----------- 0.919,58	1.087,76 ----------- 0.919,32	–0.15; +1.1	–0.3; +1.3	–0.5; +1.6
1.122,02 ----------- 0.891,25	1.122,46 ----------- 0.890,90	–0.15; +4.5	–0.3; +5.0	–0.5; +5.5
1.122,02 ----------- 0.891,25	1.122.46 ----------- 0.890.90	+2.3; +4.5[a]	+2.0; +5.0[a]	+1.6; +5.5[a]
1.294,37 ----------- 0.772,57	1.295,65 ----------- 0.771,81	+18.0; +∞	+17.5; +∞	+16.5; +∞
1.881,73 ----------- 0.531,43	1.886,95 ----------- 0.529,96	+42.5; +∞	+42; +∞	+41; +∞
3.053,65 ----------- 0.327,48	3.069,55 ----------- 0.325,78	+62; +∞	+61; +∞	+55; +∞
≥5.391,95 ----------- ≤0.185,46	≥5.434,74 ----------- ≤0.184,00	+75; +∞	+70; +∞	+60; +∞

[a] At frequencies less than the lower bandedge frequency and greater than the upper bandedge frequency, the limit on maximum relative attenuation is +∞; see figure 1.

Annex C
(informative)

Recommendations for verification of the electrical performance characteristics of bandpass filters

C.1 Table C.1 indicates which performance requirements from clauses 4 should be confirmed by the methods given in Annex D for pattern evaluation and which for periodic verification. Relevant paragraph numbers from clauses 4 and Annex D are noted within parentheses. An X in a column indicates that the test should be carried out; ---- indicates that usually no test need be carried out.

Table C.1 Verification recommendations.

Characteristic to be tested	Pattern evaluation	Periodic verification
1 Relative attenuation (4.4; D.3)	X	X (fewer frequencies)
2 Filter integrated response (4.5; D.4)	X	----
3 Linear operating range (4.6; D.5)	X	X
4 Real-time operation (4.7; D.6)	X	----
5 Antialias filter (4.8; D.7)	X	X
6 Summation of output signals (4.9; D.8)	X	X
7 FLAT frequency response (4.10; D.9)	X (if provided)	X (if provided)
8 Sensitivity to air temperature (4.14.1; D.10)	X	----
9 Sensitivity to humidity (4.14.2; D.10)	X	----

Annex D

(informative)

Test methods

D.1 General

This annex describes methods of tests that may be performed for pattern evaluation or for periodic verification to determine that the performance of a filter set continues to remain within the tolerance limits specified in clauses 4. The manufacturer may recommend equivalent tests as alternatives to those described in this annex for demonstrating conformance with the requirements of this standard. Annex C indicates recommendations for tests that may be performed for pattern evaluation and periodic verification.

The verb “shall” in this annex indicates a requirement that is mandatory in order to state that a test was performed in accordance with a test method of this annex.

All test results shall be referred to the reference environmental conditions of 4.13. The instrument under test shall be connected to a source of electrical power, turned on, and operated for at least the minimum time specified by the manufacturer before initiating any tests.

D.2 Test instruments

D.2.1 All tests to demonstrate conformance to the requirements of clause 4, except the tests to determine conformance to the frequency limit for real-time operation, utilize steady sinusoidal signals of various frequencies and signal levels. The tests for determining the frequency limits for real-time operation use a constant-amplitude sinusoidal signal the frequency of which is varied, or swept, at a logarithmic rate. The signal generator, or generators, shall be capable of producing sinusoidal test signals over the range of frequencies needed for the relative-attenuation tests of all filters in the instrument to be tested and for all filter bandwidths or bandwidth designators.

NOTE – The interval between the test frequencies is given in equation (D1).

D.2.2 At any frequency, the total distortion of a steady sinusoidal signal, including spurious components, at the output of the signal generator shall not exceed 0.01% at the maximum signal level used for a test. The frequency of a sinusoidal test signal shall be accurate within ±0.01% of the indicated frequency.

D.2.3 The level of the steady sinusoidal test signals shall be variable over at least an 80 dB range.

D.2.4 For bandpass filters that are designed to operate with measuring devices that conform to the requirements for sound level meters, the display indicator of the device should be used to measure the level of the output signal from the filter set.

D.2.5 For filter sets with digital readout devices, or with output that is available in a manufacturer-specified digital format (for example over a digital interface connection), the level of the output should be determined from the numeric readout or via the digital output to a suitable recording device.

D.2.6 For tests of real-time operation, the output level of the sweep-frequency signal generator shall be known and shall be maintained constant within ±0.1 dB of the nominal signal level over the frequency range for the selected range of nominal midband frequencies. For each 10:1 ratio of frequency over the range of frequencies covered by the frequency sweep, the logarithmic rate at which the frequency of the test signal is varied shall be constant within ±1% of the nominal sweep-frequency rate.

D.3 Relative attenuation

D.3.1 The relative attenuation characteristic of each filter in a filter set shall be measured on the reference level range. The level of the input signals shall be within 1 dB of the upper boundary of the linear operating range as stated in the Instruction Manual.

D.3.2 With the input and output of the instrument terminated, if necessary, with the impedances specified by the manufacturer, a steady sinusoidal signal is applied to the input of the filter set. The levels of input and output signals at appropriate frequencies are measured.

D.3.3 For pattern-evaluation tests, and other filter-performance-evaluation tests where the frequency of the test signal (and the measurement of input and output signal levels) is controlled automatically by a programmable device, the frequencies of the sinusoidal test signal are spaced preferably at equal intervals on a logarithmic scale centered around the exact midband frequency. If S is the number of test frequencies per filter bandwidth, the normalized frequency f_i / f_{m} of the i^{th} test signal is determined from:

$$f_i / f_{\mathrm{m}} = [G^{\,1/(bS)}]^{\,i} \tag{D1}$$

where i is a positive or negative integer, including zero. The number of test frequencies per filter bandwidth, S, shall be not less than 24. The number of test frequencies shall be increased to more than 24 per filter bandwidth when the rate of change of relative attenuation with frequency is large. The increase in the number of test frequencies per bandwidth shall be in steps of 12 until the calculated filter integrated response is independent of S to the nearest tenth of a decibel.

D.3.4 Relative attenuation $\Delta A(f/f_{\mathrm{m}})$ at any frequency f is determined from equation (8).

D.3.5 For periodic verification of conformance to the relative-attenuation requirements of 4.4, the input signal frequencies may be restricted to the 17 octave or fractional-octave-band normalized frequencies corresponding to the normalized frequencies Ω in table 1. An actual test frequency for a fractional-octave-band filter is calculated from equations (10) and (11) according to the specified system for determining an octave frequency ratio and the specified bandwidth designator.

D.4 Filter integrated response

D.4.1 Filter integrated response shall be determined from equation (13) based on numerical evaluation of the integral expression in equation (14) for normalized effective bandwidth, with relative attenuations measured as described in D.3.

D.4.2 For each filter in a filter set, the recommended procedure for numerical integration of equation (14) is by the trapezoidal rule for summation of elemental areas according to

$$B_{\mathrm{e}} = \sum_{i=-N}^{N} \left\{ \frac{10^{-0.1\Delta A\left(\frac{f_i}{f_{\mathrm{m}}}\right)} + 10^{-0.1\Delta A\left(\frac{f_{i+1}}{f_{\mathrm{m}}}\right)}}{2} \right\} \left[\frac{f_{i+1}}{f_{\mathrm{m}}} - \frac{f_i}{f_{\mathrm{m}}} \right] \tag{D2}$$

where

$\Delta A(f_i / f_{\mathrm{m}})$ is the relative attenuation in decibels measured at the i^{th} normalized test frequency;

N shall be equal to or greater than $5S = 120$ for any filter bandwidth and accuracy class.

D.5 Linear operating range

D.5.1 Linearity of the response of a filter set resulting from changes in the level of the signal at the input shall be tested with steady sinusoidal signals. Linear operating ranges shall be measured at least for the filters with the lowest and highest nominal midband frequencies of all filter bandwidths for which the Instruction Manual states that the filter set conforms to the requirements of this standard, and with FLAT frequency response, if provided, at least for the manufacturer-stated lowest and highest frequencies of the range of FLAT frequency response.

D.5.2 For each test frequency, level linearity errors on any level range shall be determined in accordance with definition 3.22 with steps of input signal level that are not greater than 5 dB. The difference between successive steps of input signal level shall be reduced to 1 dB to determine the lower and upper boundaries of a linear operating range.

D.5.3 The averaging time during a measurement shall be long enough to establish a stable indication considering the influence of internally generated noise at low input signal levels.

D.5.4 If recommended by the manufacturer, the requirements of 4.6.4 for linear operating range may be demonstrated with an input signal composed of two sinusoidal signals, one of which is the test signal and the other a subsidiary signal at a constant level 20 dB below the upper boundary of the linear operating range and at a frequency above or below the test frequency, in the frequency range for the greatest value of the applicable minimum limit for relative attenuation of filter response given in 4.4.

D.6 Real-time operation

D.6.1 The frequency range over which a filter operates in real-time shall be determined from a swept-frequency test.

D.6.2 The time-average or equivalent-continuous output signal level, L_o, indicated by the readout device at the output of the instrument should be the same for all filters when a constant-amplitude sinusoidal signal is applied to the input and the logarithm of the frequency of the signal is varied at a constant rate over the frequency range of all filters of any given bandwidth.

D.6.3 For a given swept-frequency sinusoidal input signal, the constant theoretical time-average output signal level, L_c, in decibels, that would be indicated at the output, with a relative attenuation equal to the reference attenuation of the actual filter and infinite attenuation outside the bandedge frequencies, is given by equation (15).

D.6.4 The difference δ between a measured output time-average signal level, L_o, and the measured value of the filter integrated response, ΔB, and the corresponding constant theoretical output time-average signal level, L_c, is given by

$$d = L_o - \Delta B - L_c \qquad \text{(D3)}$$

D.6.5 The test for real-time operation shall be conducted on the reference level range. The level of the input signals shall be 3 dB less than the upper boundary of the linear operating range on the reference level range as determined from the level linearity test of D.5. The logarithmic frequency sweep rate shall be low enough to permit reliable measurements of the relative attenuation in the passbands of the filters as appropriate for the filter bandwidth. The frequency at the start of the sweep f_{start} shall be approximately half the lowest nominal midband frequency for the filter bandwidth. The frequency at the end of the sweep f_{end} shall be approximately twice the corresponding greatest nominal midband frequency. The averaging time T_{avg} shall be greater than the total sweep time by at least 5 seconds.

NOTES

1 A logarithmic sweep rate in "decades" per second is determined from $[\lg(f_{end}/f_{start})]/T_{sweep}$ where f_{end} is the frequency at the end of the sweep; f_{start} is the frequency at the start of the sweep; and T_{sweep} is the sweep time in seconds.

2 The sweep rate should be not greater than 0.5 "decade" per second (or 1.6 "octave" per second).

D.6.6 Within 3seconds after initiation of the averaging time period, the frequency sweep shall be started and swept once over the frequency range from f_{start} to f_{end}. Time-average output signal levels shall be measured and compared with the calculated output signal level in accordance with equation (D3). For any filter bandwidth available in the instrument, the nominal midband frequencies where the absolute value of the difference δ first exceeds the applicable tolerance limits in 4.7 determine the low- and high-frequency limits of the frequency range for real-time operation.

D.7 Antialias filters

D.7.1 For sampled-data filters, the test of the ability of antialias filters to adequately attenuate spurious spectral components of an input signal shall be performed with steady sinusoidal signals applied to the input. The level of the input signal shall equal the measured upper boundary of the linear operating range on the reference level range.

D.7.2 For each filter bandwidth designator available in the instrument, the frequencies of the input test signal shall equal the applicable sampling frequency minus the nominal midband frequency of at least one filter in each 1:10 frequency ratio of the complete frequency range applicable to the bandwidth designator. As an example, for a range of nominal midband frequencies from 20 Hz to 20 kHz, select one nominal midband frequency in the range from 20 Hz to 200 Hz, one in the range from 200 Hz to 2 kHz, and one in the range from 2 kHz to 20 kHz.

D.7.3 For each test frequency, the level of the output signal shall not exceed the level of the input signal minus the applicable limit from table 1 on the greatest value of minimum relative attenuation.

D.8 Summation of output signals

D.8.1 Let j identify a filter in a set of filters with $j-1$ and $j+1$ representing the contiguous filters with midband frequencies lower and higher than for the j^{th} filter. Let ΔA_j, ΔA_{j-1}, and ΔA_{j+1} represent measured relative attenuations of the three filters, respectively, at any test frequency.

D.8.2 With S equal to the number of frequencies per filter bandwidth from the relative attenuation tests conducted according to the requirements of E.3, let M be equal to the largest integer just less than or equal to $S/2$ and let i be any integer between $-M$ and $+M$ to determine a frequency f_i for a measurement of relative attenuation in accordance with equation (D1).

D.8.3 At any frequency between the lower and upper bandedge frequencies of the j^{th} filter with exact midband frequency f_{m}, the difference $\Delta P(f_i)$ between the level of the input signal minus the reference attenuation and the level of the summed output signals is determined from the relationship

$$\Delta P(f_i) = 10\,\lg\left(10^{-0.1\Delta A_{j-1}} + 10^{-0.1\Delta A_j} + 10^{-0.1\Delta A_{j+1}}\right) \tag{D4}$$

where

ΔA_{j-1} is the relative attenuation measured at normalized frequency $G^{[i/(bS)+1/b]}$;

ΔA_j is the relative attenuation measured at normalized frequency $G^{[i/(bS)]}$;

ΔA_{j+1} is the relative attenuation measured at normalized frequency $G^{[i/(bS)-1/b]}$.

D.8.4 The test shall be carried out from the lowest midband frequency to the highest midband frequency of the filter set.

D.8.5 For any filter bandwidth provided, the difference $\Delta P(f_i)$ calculated according to equation (D4) shall be within the tolerance limits given in 4.9 at any test frequency between any two octave or fractional-octave midband frequencies.

D.9 FLAT frequency response

For filter sets that provide a range of FLAT frequency response, the extent of the frequency range, over which the tolerance limits on relative attenuation in 4.10 are maintained, shall be tested by applying constant-level sinusoidal signals to the input and noting the corresponding output signal levels. The level of the input signals shall equal the reference input signal level on the reference level range. The frequencies of the test signals include the manufacturer's stated lower and upper limits of the range of FLAT frequency response and the nominal midband frequencies of the octave-band filters between the lower and upper frequency limits.

D.10 Sensitivity to variations of air temperature and relative humidity

Tests shall be carried out to ensure that the filter satisfies the requirements for the range of ambient air temperatures given in 4.14.1 and for the effect of relative humidity given in 4.14.2. For temperature tests, the exposure time at each ambient temperature shall be long enough to permit the instrument under test to reach equilibrium with the prevailing temperature.

D.11 Sensitivity to radio-frequency electromagnetic fields

The manufacturer should determine the influence of radio-frequency electromagnetic fields in accordance with ANSI S1.14 (R2003).

Acoustical Society of America

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Errata to ANSI S1.11-2004 American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

Page 4 contains text that is not related to the definition above it (3.32). Delete the text at the bottom of the right-hand column beginning with the word "according" and ending with the word "instrument."

Page 9 Three words were omitted from sub clause 4.14.2. The omitted words are underlined below. The clause should read:

4.14.2 Relative humidity. The manufacturer shall state the range of relative humidity and corresponding air temperature over which the instrument can operate continuously. After a 24 <u>hour exposure to</u> the humid atmosphere at a relative humidity of 75%, and at an ambient air temperature of +40 ^{o}C and without condensation on internal components of the instrument under test, the relative attenuation at the nominal midband frequency for any filter available in the instrument shall not deviate from the relative attenuation at the same frequency under reference environmental conditions by more than ±0.15 dB, ±0.3 dB, and ±0.5 dB for class 0, 1, and 2 instruments, respectively.