ANSI S3.5-1997
Revision of
ANSI S3.5-1969 (R 1986)

American National Standard

Methods for Calculation of the Speech Intelligibility Index

Secretariat
Acoustical Society of America

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Abstract

This Standard defines a method for computing a physical measure that is highly correlated with the intelligibility of speech as evaluated by speech perception tests given a group of talkers and listeners. This measure is called the Speech Intelligibility Index, or SII. The SII is calculated from acoustical measurements of speech and noise. This standard is **not** a substitute for ANSI S3.2-1989 (R 1995) *American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems.*

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Foreword

[This Foreword is for information only and is not an integral part of ANSI S3.5-1997 *American National Standard Methods for Calculation of the Speech Intelligibility Index.*]

This Standard defines a method for computing a physical measure that is highly correlated with the intelligibility of speech under a variety of adverse listening conditions, such as noise, filtering, and reverberation. It is a major revision of ANSI S3.5-1969 (R 1986), *American National Standard Methods for the Calculation of the Articulation Index*. The most important changes in the present version of the Standard relate to the need to provide a general framework into which various methods for determining the input variables of the Speech Intelligibility Index model (e.g., the equivalent speech spectrum level, the equivalent noise spectrum level, and the equivalent hearing threshold level) can be incorporated. For some applications these methods already exist (e.g., the modulation transfer function for determining the apparent speech-to-noise ratio in reverberation), while others still may be developed in future revisions of this Standard. In addition, the generality of the Standard has been extended to include various measurement points (e.g., free-field for architectural acoustics or eardrum for telephony). The other changes of the Standard are due to new data which have been accumulated since 1969 for various parameters and procedures used in the calculations. These new data include spread of masking, standard speech spectrum level, and relative importance of various frequencies to speech intelligibility. Finally, the name has been changed from the Articulation Index to the Speech Intelligibility Index (SII). In this Standard, *speech intelligibility* refers to how well an individual understands speech.

It should be noted that SII should **not** be used as a substitute for determining speech intelligibility as described in ANSI S3.2-1989 (R 1995), *American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems*.

This Standard was developed under the jurisdiction of Accredited Standards Committee S3, Bioacoustics, which has the following scope:

> *Standards, specifications, methods of measurement and test, and terminology, in the fields of psychological and physiological acoustics, including aspects of general acoustics, shock and vibration which pertain to biological safety, tolerance, and comfort.*

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Working Group S3/WG 79, Calculation of the Speech Intelligibility Index, which assisted Accredited Standards Committee S3, Bioacoustics, in the development of this Standard, had the following membership:

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Suggestions for improvement will be welcomed. Send suggestions for improvement in writing to Accredited Standards Committee S3, Bioacoustics, in care of the ASA Standards Secretariat, 120 Wall Street, 32nd floor, New York, New York 10005-3993, USA, Telephone: + 1 212 248 0373; FAX: +1 212 248 0146; E-mail: asastds@aip.org.

American National Standard

Methods for Calculation of the Speech Intelligibility Index

1 Scope, purpose and applications

1.1 Scope

The predictions of this Standard apply to listening conditions where the input variables of the Speech Intelligibility Index (SII) model can be accurately estimated. The input variables include the equivalent speech spectrum level, the equivalent noise spectrum level, and the equivalent hearing threshold level. This includes the conditions where either speech or noise may not exist as directly measurable physical quantities (e.g., conditions where speech correlated noise is present, such as reverberated speech) but where equivalent speech spectrum level, equivalent noise spectrum level, and equivalent hearing threshold level can, nevertheless, be calculated. The predictions made by use of this Standard are correct only on the average, that is, across a group of talkers and a group of listeners of both genders. The scope of the Standard is limited to natural speech, otologically normal listeners, and communication conditions which do not include multiple, sharply filtered bands of speech or sharply filtered noise. In addition, the listeners should have no linguistic or cognitive deficiencies with respect to the language used.

1.2 Purpose

This Standard defines methods for computing a measure, called the Speech Intelligibility Index (SII), that is highly correlated with the intelligibility of speech under a variety of adverse listening conditions, such as noise masking, filtering, and reverberation. The SII is computed from acoustical measurements or estimates of speech spectrum level, from noise spectrum level, and from psychoacoustical measurements or estimates of hearing threshold level. Various frequencies contribute different amounts to speech intelligibility, and, within a certain range, a higher speech-to-noise ratio contributes to intelligibility. By measuring the speech-to-noise ratio in each contributing frequency band and adding the results, the intelligibility of a speech communication system can be predicted.

1.3 Applications

SII procedures in this Standard consist of several parts. Clause 4 specifies calculation methods when the input variables (i.e., equivalent speech spectrum level, equivalent noise spectrum level, and equivalent hearing threshold level) are known. The application domain of this framework is quite general and extends to all listening conditions, within the scope of the Standard, where adequate methods for specifying these input variables exist.

Measurement and calculation procedures for specifying the input variables with which to calculate SII for a number of conditions encountered in practice, such as external noise masking, reverberant speech, monaural listening, and some conditions of binaural listening are provided in clause 5.

Extension of the SII calculation methods to individuals with hearing loss is contained in annex A. Annex B provides procedures for taking into account the content of speech materials in the assessment of speech intelligibility.

Examples of the basic SII computational procedures applied to octave and one-third octave frequency band procedures are contained in annex C.

2 References

The following Standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of approval by the American National Standards Institute, Inc. (ANSI), the editions indicated were valid. Because Standards are revised from time to time, users should consult the latest version approved by the American National Standards Institute. For purposes of this Standard, the use of the latest revision of a referenced Standard is not mandatory. Information on recent editions is available from the ASA Standards Secretariat.

2.1 Normative references

[1] ANSI S3.2-1989 (R 1995) *American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems.*

[2] ANSI S3.6-1996 *American National Standard Specifications for Audiometers*.

[3] ANSI S3.20-1995 *American National Standard Bioacoustical Terminology*.

[4] ANSI S3.21-1978 (R 1997) *American National Standard Method for Pure-tone Threshold Audiometry*.

[5] ANSI S3.35-1985 (R 1997) *American National Standard Method of Measurement of Performance Characteristics of Hearing Aids under Simulated in situ Working Conditions*.

2.2 Informative references

[6] Bentler, R. and Pavlovic, C.V. (1989) "Transfer functions and correction factors used in hearing aid evaluation and research," *Ear and Hearing* **10**, 58-63.

[7] Dugal, R.L., Braida, L.D., and Durlach, N.I. (1978) "Implications of previous research for the selection of frequency-gain characteristics," in *Acoustical Factors Affecting Hearing Aid Performance*, edited by B.A. Studebaker & I. Hochberg, University Park, Baltimore, MD, 379-403.

[8] French, N.R. and Steinberg, J.C. (1947) "Factors governing the intelligibility of speech sounds," *J. Acoust. Soc. Am.* **19**, 90-119.

[9] Kryter, K.D. (1962) "Methods for the calculation and use of the articulation index," *J. Acoust. Soc. Am.* **34**, 1689-1697.

[10] Ludvigsen, C. (1985) "Relations among some psychoacoustic parameters in normal and cochlearly impaired listeners," *J. Acoust. Soc. Am.* **78**, 1271-1280.

[11] Pavlovic, C.V. (1987) "Derivation of primary parameters and procedures for use in speech intelligibility predictions," *J. Acoust. Soc. Am.* **82**, 413-422.

[12] Pavlovic, C.V., Rossi, M., and Espesser, R. (1990) "Statistical distribution of speech for various languages," *J. Acoust. Soc. Am.* **88**, Suppl. 1, S176.

[13] Pearsons, K.S., Bennett, R.L., and Fidell, S. (1978) "Speech Levels in Various Environments," Bolt, Beranek and Newman Report 3281, as cited in Skinner, M.W., *Hearing Aid Evaluation*, Prentice-Hall, Englewood Cliffs, N.J. 14-16.

[14] Schroeder, M. (1981) "Modulation transfer functions: definition and measurement," *Acustica* **49**(3), 179-182.

[15] Steeneken, H.J.M. and Houtgast, T. (1980) "A physical method for measuring speech-transmission quality," *J. Acoust. Soc. Am.* **67**, 318–326.

[16] Studebaker, G.A., Taylor, R., and Sherbecue, R.L. (1994) "The effect of noise spectrum on speech recognition performance-intensity functions," *J. Speech. Hear. Res.* **37**(2), 439-448.

[17] Zwicker, E. (1961) "Subdivision of audible frequency range into critical bands," *J. Acoust. Soc. Am.* **33**, 248.

3 Definitions

For the purpose of this Standard, the following terms apply:

NOTE - Some of the following definitions have been adapted from S3.20-1995 for use in this Standard.

3.1 band importance function. For a given frequency band specified by frequency f_i, a numerical value characterizing the relative significance of this frequency band to speech intelligibility. Symbol, I_i.

NOTES

1 Band importance functions are listed for different speech intelligibility index computational procedures in tables 1–4.

2 Band importance function depends on the type of speech material whose intelligibility needs to be predicted. As used in this Standard, it applies to *average speech*. It produces accurate predictions across different communication situations and for communication situations where contextual, linguistic, semantic, and syntactic constraints vary within a situation. The user interested in predicting speech intelligibility for a specific speech material should refer to annex B, where band importance functions for a number of speech tests are given.

3 Reference 11 contains details on the derivation of the band importance function.

3.2 band audibility function. For a given frequency band designated by frequency f_i, a numerical value between 0.0 and 1.0 specifying the effective proportion of the speech dynamic range within the band that contributes to speech intelligibility under conditions which are less than optimal (e.g., the presence of noise or reverberation, a high presentation level, some speech frequencies below the threshold of hearing, etc). Symbol, A_i.

3.3 speech intelligibility index (SII). Product of band importance function and band audibility func-

Table 1 — Critical band SII procedure — frequencies, band importance function, standard speech spectra, internal noise, hearing threshold levels, and free-field to eardrum transfer function.

Critical band				Standard speech spectrum level for stated vocal effort, dB				Reference internal noise spectrum level dB	Free-field to eardrum transfer function dB
Band no.	Center freq Hz	Band limits Hz	Band import-ance	Normal	Raised	Loud	Shout		
1	150	100-200	0.0103	31.44	34.06	34.21	28.69	1.50	0.60
2	250	200-300	0.0261	34.75	38.98	41.55	42.50	-3.90	1.00
3	350	300-400	0.0419	34.14	38.62	43.68	47.14	-7.20	1.40
4	450	400-510	0.0577	34.58	39.84	44.08	48.46	-8.90	1.40
5	570	510-630	0.0577	33.17	39.44	45.34	50.17	-10.30	1.90
6	700	630-770	0.0577	30.64	37.99	45.22	51.68	-11.40	2.80
7	840	770-920	0.0577	27.59	35.85	43.60	51.43	-12.00	3.00
8	1000	920-1080	0.0577	25.01	33.86	42.16	51.31	-12.50	2.60
9	1170	1080-1270	0.0577	23.52	32.56	41.07	49.40	-13.20	2.60
10	1370	1270-1480	0.0577	22.28	30.91	39.68	49.03	-14.00	3.60
11	1600	1480-1720	0.0577	20.15	28.58	37.70	47.65	-15.40	6.10
12	1850	1720-2000	0.0577	18.29	26.37	35.62	45.47	-16.90	10.50
13	2150	2000-2320	0.0577	16.37	24.34	33.17	43.13	-18.80	13.80
14	2500	2320-2700	0.0577	13.80	22.35	30.98	40.80	-21.20	16.80
15	2900	2700-3150	0.0577	12.21	21.04	29.01	39.15	-23.20	15.80
16	3400	3150-3700	0.0577	11.09	19.56	27.71	37.30	-24.90	14.90
17	4000	3700-4400	0.0577	9.33	16.78	25.41	34.41	-25.90	14.30
18	4800	4400-5300	0.0460	5.84	12.14	19.20	29.01	-24.20	12.40
19	5800	5300-6400	0.0343	3.47	9.04	15.37	25.17	-19.00	7.90
20	7000	6400-7700	0.0226	1.78	6.36	12.61	22.08	-11.70	4.30
21	8500	7700-9500	0.0110	-0.14	3.44	9.62	18.76	-6.00	0.50
Overall SPL, dB				62.35	68.34	74.85	82.30		

tion, summed over the total number of frequency bands in the computational method. In symbols:

$$S = \sum_{i=1}^{n} I_i A_i \qquad (1)$$

where n is the number of SII computational bands, while I_i and A_i are the values of the band importance function and the band audibility function associated with the frequency band designated by the summation index i.

NOTES

1 Combination rules other than addition of the products I_i and A_i may be used to improve predictions under some circumstances, but are not considered in this Standard.

2 The calculated SII is not converted to any corresponding speech intelligibility score. It may be interpreted as a proportion of the total number of speech cues available to the listener. The maximal value of the SII, 1.0, signifies that all speech cues reach the listener, while its minimum value, 0.0, signifies that no speech cues are available to the listener. The SII value of 0.5 would likewise suggest that half of the speech cues are delivered to the listener.

3.4 SII computational procedures. Method for calculating speech intelligibility index taking into account band importance function, speech spectrum level, and noise spectrum level. (See clauses 4 and 5.)

NOTES

1 Depending on the number and size of discrete frequency bands used in the SII calculations, different SII computational procedures can be implemented. In this Standard, four computational procedures are provided. In the order of accuracy they are:

Table 2 — Equally-contributing (17 band) critical-band SII procedure — frequencies, band importance function, standard speech spectra, internal noise, hearing threshold levels, and free-field to eardrum transfer function.

	Critical band			Standard speech spectrum level for stated vocal effort, dB				Reference internal noise spectrum level dB	Free-field to eardrum transfer function dB
Band no.	Center freq Hz	Band limits Hz	Band import-ance	Normal	Raised	Loud	Shout		
1	350	300-400	0.0588	34.14	38.62	43.68	47.14	-7.20	1.40
2	450	400-510	0.0588	34.58	39.84	44.08	48.46	-8.90	1.40
3	570	510-630	0.0588	33.17	39.44	45.34	50.17	-10.30	1.90
4	700	630-770	0.0588	30.64	37.99	45.22	51.68	-11.40	2.80
5	840	770-920	0.0588	27.59	35.85	43.60	51.43	-12.00	3.00
6	1000	920-1080	0.0588	25.01	33.86	42.16	51.31	-12.50	2.60
7	1170	1080-1270	0.0588	23.52	32.56	41.07	49.40	-13.20	2.60
8	1370	1270-1480	0.0588	22.28	30.91	39.68	49.03	-14.00	3.60
9	1600	1480-1720	0.0588	20.15	28.58	37.70	47.65	-15.40	6.10
10	1850	1720-2000	0.0588	18.29	26.37	35.62	45.47	-16.90	10.50
11	2150	2000-2320	0.0588	16.37	24.34	33.17	43.13	-18.80	13.80
12	2500	2320-2700	0.0588	13.80	22.35	30.98	40.80	-21.20	16.80
13	2900	2700-3150	0.0588	12.21	21.04	29.01	39.15	-23.20	15.80
14	3400	3150-3700	0.0588	11.09	19.56	27.71	37.30	-24.90	14.90
15	4000	3700-4400	0.0588	9.33	16.78	25.41	34.41	-25.90	14.30
16	4800	4400-5300	0.0588	5.84	12.14	19.20	29.01	-24.20	12.40
17	5800	5300-6400	0.0588	3.47	9.04	15.37	25.17	-19.00	7.90
Overall SPL, dB				62.35	68.34	74.85	82.30		

(1) Critical band procedure (21 bands),

(2) One-third octave band procedure (18 bands),

(3) Equally-contributing critical band procedure (17 bands),

(4) Octave band procedure (6 bands).

2 The octave band procedure should not be used if either the speech level or the noise level varies greatly within any one octave.

3.5 reference communication situation. Specific set of conditions assumed in the computation of speech intelligibility index:

1) Listener faces both the speech and noise source in an otherwise free field or noise and speech are assumed to be omnidirectional sound sources,

2) Listening is monaural,

3) The speech and noise sound sources are independent of each other and their properties can be accurately measured in the absence of the other.

NOTE - For communication situations that do not satisfy these conditions (e.g., binaural listening) see 3.11 and 3.15.

3.6 speech spectrum level. Level of the limit, as the width of the frequency band approaches zero, of the ratio of the quotient of the time-mean-square pressure of a speech signal in a specified frequency band, by the width of the band, to the quotient of the square of the reference pressure of 20μPa by the reference bandwidth of 1 Hz. Unit, decibel (dB).

NOTES

1 Speech literature often refers to speech spectrum level as being the "power" average over time of speech sound pressure level contained within a frequency band 1 Hz in width.

2 In symbols, speech spectrum level $E(f)$ is expressed as:

$$E(f) = 10 \lg \{ \lim_{\Delta f \to 0} [p_f^2(f)/\Delta f] / [p_o^2 / \Delta_0 f] \} \quad (2)$$

Table 3 — One-third octave band SII procedure — frequencies, band importance function, standard speech spectra, internal noise, hearing threshold levels, and free-field to eardrum transfer function.

	Frequency band			Standard speech spectrum level for stated vocal effort, dB				Reference internal noise spectrum level dB	Free-field to eardrum transfer function dB
Band no.	Nominal midband freq Hz	Band width adj, Δ dB	Band importance	Normal	Raised	Loud	Shout		
1	160	15.65	0.0083	32.41	33.81	35.29	30.77	0.60	0.00
2	200	16.65	0.0095	34.48	33.92	37.76	36.65	-1.70	0.50
3	250	17.65	0.0150	34.75	38.98	41.55	42.50	-3.90	1.00
4	315	18.65	0.0289	33.98	38.57	43.78	46.51	-6.10	1.40
5	400	19.65	0.0440	34.59	39.11	43.30	47.40	-8.20	1.50
6	500	20.65	0.0578	34.27	40.15	44.85	49.24	-9.70	1.80
7	630	21.65	0.0653	32.06	38.78	45.55	51.21	-10.80	2.40
8	800	22.65	0.0711	28.30	36.37	44.05	51.44	-11.90	3.10
9	1000	23.65	0.0818	25.01	33.86	42.16	51.31	-12.50	2.60
10	1250	24.65	0.0844	23.00	31.89	40.53	49.63	-13.50	3.00
11	1600	25.65	0.0882	20.15	28.58	37.70	47.65	-15.40	6.10
12	2000	26.65	0.0898	17.32	25.32	34.39	44.32	-17.70	12.00
13	2500	27.65	0.0868	13.18	22.35	30.98	40.80	-21.20	16.80
14	3150	28.65	0.0844	11.55	20.15	28.21	38.13	-24.20	15.00
15	4000	29.65	0.0771	9.33	16.78	25.41	34.41	-25.90	14.30
16	5000	30.65	0.0527	5.31	11.47	18.35	28.24	-23.60	10.70
17	6300	31.65	0.0364	2.59	7.67	13.87	23.45	-15.80	6.40
18	8000	32.65	0.0185	1.13	5.07	11.39	20.72	-7.10	1.80
Overall SPL, dB				62.35	68.34	74.85	82.30		

Table 4 — Octave band SII procedure — frequencies, band importance function, standard speech spectra, internal noise, hearing threshold levels, and free-field to eardrum transfer function.

	Frequency band			Standard speech spectrum level for stated vocal effort, dB				Reference internal noise spectrum level dB	Free-field to eardrum transfer function dB
Band no.	Nominal midband freq Hz	Band width adj, Δ dB	Band Importance	Normal	Raised	Loud	Shout		
1	250	22.48	0.0617	34.75	38.98	41.55	42.50	-3.90	1.00
2	500	25.48	0.1671	34.27	40.15	44.85	49.24	-9.70	1.80
3	1000	28.48	0.2373	25.01	33.86	42.16	51.31	-12.50	2.60
4	2000	31.48	0.2648	17.32	25.32	34.39	44.32	-17.70	12.00
5	4000	34.48	0.2142	9.33	16.78	25.41	34.41	-25.90	14.30
6	8000	37.48	0.0549	1.13	5.07	11.39	20.72	-7.10	1.80
Overall SPL, dB				62.35	68.34	74.85	82.30		

where p_f^2 is the time-mean-square speech sound pressure measured through a frequency filter with bandwidth Δf, p_o is the reference sound pressure of 20 μPa, and $\Delta_0 f$ is the reference bandwidth of 1 Hz.

3 In actual applications, speech level is measured at the output of a band-pass filter wider than 1 Hz. If the speech sound pressure level at the output of the filter (band level) centered at the frequency f is $E_b(f)$, then the speech spectrum level, $E(f)$ can be approximated as:

$$E(f) = E_b(f) - 10 \lg [\Delta(f)/\Delta_0 f] \qquad (3)$$

where $\Delta(f)$ is the filter bandwidth and $\Delta_0 f$ is the reference bandwidth of 1 Hz. For SII applications, $\Delta(f)$ should not be substantially larger than the width of the SII calculation band.

4 For SII applications it is assumed that pauses between words occurring within an utterance pronounced in a normal, connected manner are an integral part of a speech signal and should not be eliminated in any measurement of the speech spectrum.

3.7 overall speech level. Ten times the logarithm to the base ten of the square of the ratio of the time-mean-square speech pressure, in the frequency range between the lowest and highest frequency of the speech signal, to the square of the reference pressure of 20 μPa. Unit, decibel (dB).

3.8 apparent speech spectrum level. Spectrum level for speech assumed for use in calculations where physical measurement of the actual speech spectrum levels is not feasible because of interfering or otherwise disturbing conditions, e.g., reverberation. Unit, decibel (dB).

3.9 standard speech spectrum level. Spectrum level of speech measured one meter directly in front of the talker's lips, in a free sound field, for a specified vocal effort, in quiet, averaged across a large group of adult male and female talkers. Unit, decibel (dB).

NOTE - Standard speech spectrum levels are specified in tables 1-4 for four degrees of vocal effort: *normal, raised, loud,* and *shouted*.

3.10 idealized speech spectrum level. For a normal vocal effort, sound pressure spectrum level of 35 dB from 100 to 500 Hz, decreasing at frequencies greater than 500 Hz at the rate of 9 dB per octave. For raised, loud, and shouting vocal efforts, the normal voice spectrum levels are increased by 7.8 dB for each incremental step of vocal effort. Unit, decibel (dB).

NOTE - For measurement procedures where generation of speech-like signals is required, it may be more convenient to work with the *idealized*, rather than the standard, speech spectrum level.

3.11 equivalent speech spectrum level. Speech spectrum level measured (or the apparent speech spectrum level assumed) at the point corresponding to the center of the listener's head (midpoint between the ears), with the listener absent, if the communication situation satisfies the conditions of the reference communication situation. Unit, decibel (dB).

NOTES

1 Many communication situations do not satisfy the conditions of the reference communication situation. In those instances, the equivalent speech spectrum level is defined as the speech spectrum level, or the apparent speech spectrum level, that would have been measured under the reference communication situation at the center of the listener's head (midpoint between the ears) with the listener absent, while producing in the ear of the listener (at the eardrum) the same sound pressure level that exists under the actual circumstances. This definition presupposes either monaural listening or the same signals in the left and in the right ears. For other conditions of binaural listening, the equivalent speech spectrum level may include appropriate corrections to account for the effects of binaural asymmetry.

2 At the time this Standard was developed, SII procedures existed only for a limited number of binaural listening conditions. The definition of the equivalent speech spectrum level, as well as the definitions of the equivalent noise spectrum level and the equivalent hearing threshold level allow the general SII protocol, described in clause 3.4, to be used once other binaural procedures have been developed in future revisions of this Standard.

3 As an example, at 1000 Hz the speech spectrum level at the eardrum of the listener is 50 dB when the signal is delivered by a telephone receiver. The free-field-to-eardrum transfer function at this frequency is 2.6 dB (table 1). The equivalent speech spectrum level is 50 − 2.6 dB = 47.4 dB. That is, if the listener were listening to a sound spectrum level of 47.4 dB in a free field, a spectrum level of 50 dB would be measured at the eardrum of the listener, which is the same level as in the actual telephone communication.

3.12 self-speech masking spectrum level. Equivalent speech spectrum level (see 3.11) minus 24 dB. In conditions of severe low-pass or band-pass filtering, this variable is used to calculate masking of higher speech frequencies by lower speech frequencies. Unit, decibel (dB).

3.13 noise spectrum level. Sound pressure spectrum level of noise. In this Standard, the term noise includes both noise noncorrelated with the speech signal (e.g., external noise, babble), as well as noise correlated with the speech signal (e.g., reverberated speech). Unit, decibel (dB).

3.14 apparent noise spectrum level. Spectrum level assumed when it is not feasible to measure the noise spectrum level directly for a particular application where SII calculations are to be made. Unit, decibel (dB).

3.15 equivalent noise spectrum level. Noise spectrum level measured (or the apparent noise spectrum level assumed) at the point corresponding to the center of the listener's head (mid-point between the ears), with the listener absent, under the reference communication situation. Unit, decibel (dB).

NOTE - For situations other than reference, the equivalent noise spectrum level is defined as the noise spectrum level that would have been measured under the reference communication situation at the center of the listener's head (mid-point between the ears) with the listener absent, while producing in the ear of the listener (at the eardrum), the same sound pressure level that exists under the actual circumstances. This definition presupposes either monaural listening or the same signals in the left and in the right ears. For other conditions of binaural listening, the equivalent noise spectrum level may include appropriate corrections to account for the effects of binaural asymmetry.

3.16 equivalent masking spectrum level. Sound pressure spectrum level that appropriately accounts for the masking of speech produced by the equivalent noise. This masking includes within-band masking, out-of-band masking (spread of masking), as well as masking of one speech frequency by another (self-speech masking). Unit, decibel (dB).

3.17 combined speech and noise spectrum level (CSNSL). Spectrum level of the time-mean-square sum of the combined speech and noise sound pressures. Unit, decibel (dB).

3.18 apparent speech-to-noise ratio. At a specified frequency, the difference, in decibels, between the apparent speech spectrum level and the apparent noise spectrum level.

3.19 otologically normal listener. Person in a normal state of health who is free from all signs and symptoms of ear disease and from occlusive earwax in the ear canal and has no history of excessive exposure to noise.

3.20 pure-tone threshold level. At a specific frequency, the minimum sound pressure level of the pure tone that is capable of evoking an auditory sensation as determined by an appropriate psychoacoustical method. The actual value of the pure-tone threshold level depends on the selected psychoacoustical method, measurement apparatus (e.g., type of earphone), and the place of measurement. Unit, decibel (dB).

3.21 reference pure-tone threshold level. Mean value, at a specific frequency, of the pure-tone threshold levels of a large number of ears of otologically normal subjects within the age limit of 18-30 years inclusive. The actual value of the reference pure-tone threshold level depends on the selected psychoacoustical method, measurement apparatus (e.g., type of earphone), and the place of measurement. Unit, decibel (dB).

3.22 hearing threshold level. Pure-tone threshold level of a given ear at a specified frequency minus the reference pure-tone threshold level. The same psychoacoustical procedure, the same measurement apparatus, and the same place of measurement are used for obtaining both the pure-tone threshold level and the reference puretone threshold level. Abbreviation, HL; unit, decibel (dB).

3.23 equivalent hearing threshold level. For monaural listening conditions, at a specified frequency, hearing threshold level arithmetically averaged across the group of ears of the listeners for whom the SII calculations are performed. For binaural listening conditions, equivalent hearing threshold level may, in an appropriate manner, account for the hearing threshold levels of both the right and left ears. Unit, decibel (dB).

3.24 reference internal noise spectrum level. Spectrum level of a fictitious internal noise in the ear of the listener, which, if it were an external masker, would give rise to the reference pure-tone threshold. The reference pure-tone threshold is obtained in the free-field where the listener faces the source and is measured at the center of the listener's head (mid-point between the ears; listener absent) using either the psychoacoustical method of constant stimuli (50% identification rate, 1 dB step size) or the psychoacoustical method of limits (1 dB step size).

NOTES

1 Reference internal noise spectrum level is given in tables 1-4 for different SII procedures of this Standard.

2 In earlier documents reference internal noise spectrum level has been labeled *threshold for sounds having continuous spectra* (reference 9), or

threshold spectrum density (reference 11). The reference internal noise spectrum level listed in tables 1-4 is derived from reference 11, and is equal to the reference pure-tone threshold level minus 10 times the logarithm to the base 10 of the critical ratio reported by Zwicker (reference 17).

3.25 equivalent internal noise spectrum level. The reference internal noise spectrum level increased by the equivalent hearing threshold level. Unit, decibel, (dB).

3.26 equivalent disturbance spectrum level. Larger of the equivalent internal noise spectrum level and the equivalent masking spectrum level. Unit, decibel (dB).

3.27 speech level distortion factor. Factor which accounts for the decrease in the intelligibility of speech at high presentation levels (reference 8). The maximum value of 1 is obtained when there is no distortion due to the presentation level. Its value decreases to a minimum of zero at high presentation levels.

3.28 insertion gain. For an amplification or attenuation device (e.g., ear protector) worn by a listener, at a specific frequency, the difference in decibels between the pure-tone sound pressure level at the eardrum with the amplification/ attenuation device in place and the pure-tone sound pressure level at the eardrum with the device removed.

3.29 free-field-to-eardrum transfer function. Difference, in decibels, between the pure-tone sound pressure level at the eardrum (listener facing the source) and the pure-tone sound pressure level at the center of the listener's head with the listener absent.

NOTES

1 The free-field-to-eardrum transfer function is listed in tables 1-4 for different SII calculation procedures.

2 See reference 6 for the derivation of the free-field-to-eardrum transfer function.

3.30 modulation index. Numerical value, between 0 and 1.0, with symbol m, that multiplies a modulation function where a signal is varied in time *t*, at frequency *f*, in proportion to $1+m\cos 2\pi ft$.

3.31 modulation transfer function for intensity, MTFI. Modulation index of a squared measure of the signal at the output of a system when the square of the same measure for the input signal is modulated with a modulation index of 1.

3.32 List of symbols

- *A* Band audibility function.
- *B* Larger of the spectrum levels for equivalent noise and self-speech masking, dB
- *C* Slope per octave (doubling of frequency) of the upward spread of masking, dB/octave
- *D* Spectrum level for equivalent disturbance, dB
- *d* Distance from the speech source to the center of the listener's head, m.
- *E* Spectrum level of measured, estimated, or apparent speech at a specified point, dB.
- *E'* Spectrum level of equivalent speech, dB.
- *F* Center frequency of an SII band, Hz.
- *f* Frequency, Hz.
- *G* Insertion gain, dB.
- *H* Free-field-to-eardrum transfer function, dB.
- *h* High (upper) limiting frequency of an SII band, Hz.
- *I* Band importance function.
- i Individual band number used in calculation of SII
- *K* Temporary variable used in the calculation of the band audibility function.
- k Individual band number.
- *L* Speech level distortion factor, dB.
- *l* Low limiting frequency of an SII band, Hz.
- M Modulation transfer function for intensity, MTFI.
- m Modulation index.
- *N* Spectrum level of measured, estimated, or apparent noise at a specified point, dB.
- *N'* Spectrum level of equivalent noise, dB.
- n Number of bands in an SII procedure.
- *P* Spectrum level of combined speech and noise, CSNSL, dB.
- *R* Apparent speech-to-noise ratio, dB.
- S Speech intelligibility index (SII).
- *T* Hearing threshold level, dB.
- *T'* Equivalent hearing threshold level, dB.
- *t* Time, s.
- *U* Spectrum level of standard speech for normal vocal effort, dB.
- *V* Spectrum level for self-speech masking, dB.
- *X* Spectrum level of internal noise, dB.
- *X'* Spectrum level of equivalent internal noise, dB.
- *Z* Spectrum level for equivalent masking, dB.

NOTES

1 The term "center frequency" used in this Standard is that commonly used in the literature on speech research to designate the approximate middle of a frequency passband. It is not the same as the term "midband frequency," either "nominal" or "exact," used in standards on acoustical instrumentation. Similarly, the numerical values used as band numbers for indexing bands in summation processes of this Standard are not the same as the band numbers in S1.6 for preferred frequencies.

2 Additional symbols appearing only in notes in this Standard are not included in the above list, but are identified in the note where they are introduced.

NOTES

1 See clause 3.10 for spectra of *idealized* speech, as compared to the spectra for *standard speech* listed in tables 1-4.

2 See clause 5.1.3 for *approximate* speech spectra, which, at increased vocal effort, retain the same relative frequency distribution as the spectrum at normal vocal effort, increased only in actual sound pressure levels.

3 The overall SPL listed in tables 1-4 is calculated over the entire frequency range of speech, as specified in 3.7. Since the sound levels listed in the tables are for specific frequency bands, their mean-square sum is not exactly the same as the overall SPL.

4 Methods for calculating Speech Intelligibility Index, SII

SII may be computed by four different methods, which although conceptually the same, differ in some details. The four methods differ essentially by the number and size of the frequency bands used in computation of SII. In descending order of accuracy, the four methods are:

1) Critical frequency band, (21 bands),

2) One-third octave frequency band , (18 bands),

3) Equally-contributing critical band, (17 bands),

4) Octave frequency band, (6 bands).

The basic steps in the computation procedures are the same for all procedures; they differ only in detail. In the following specifications, differences between the four methods are specified individually, where they exist, as branches in the computational process. Examples of the octave band and one-third octave band methods are provided in annex C.

4.1 Step 1 — Select calculation method

Select one of the four choices listed in 4, depending upon the choice of frequency bands used for the calculation. Tables 1-4 list the frequency bands, band importance functions, spectrum levels of standard speech for different vocal efforts, reference internal noise spectra, and free-field to eardrum transfer functions for each of the four methods. The choice of any one method may be influenced by the availability of data to determine the spectrum levels for the equivalent noise spectra and equivalent hearing thresholds. Clause 5 of this Standard provides methods for determining these quantities for some situations.

4.2 Step 2 — Equivalent speech, noise, and hearing threshold spectra

The choice of calculation method determines the frequency bands and the band center frequencies at which spectrum levels are required. Using methodology from clause 5, specify:

1) equivalent speech spectrum level, E',

2) equivalent noise spectrum level, N',

3) equivalent hearing threshold level, T'.

Alternatively, speech spectra may be specified by the procedures for determining approximate spectrum levels from measured data, see clause 5.1.3, or by using idealized spectra in accordance with clause 3.10.

NOTE - In the absence of an external noise or an apparent noise, assume the equivalent noise spectrum level is -50 dB for each calculation band.

4.3 Step 3 — Equivalent masking spectrum level, Z_i

4.3.1 Octave band procedure. For the i-th calculation band, the equivalent masking spectrum level, Z_i, is equal to the equivalent noise spectrum level, N'_i:

$$Z_i = N'_i \qquad (4)$$

NOTE - The spectrum level of noise present in a speech environment is often estimated from sound pressure levels measured in frequency bands one-third or full octave wide. Noise spectrum level, N', may be estimated from such measurements by subtracting the bandwidth adjustment, in decibels, as indicated in equation 3. These adjustments are listed in table 3 for one-third octave frequency bands and in table 4 for octaves.

4.3.2 Critical band, equally-contributing critical band, and one-third octave band procedures

4.3.2.1 For each calculation band i, determine the self-speech masking spectrum level, V_i:

$$V_i = E'_i - 24 \qquad (5)$$

where E'_i is the equivalent speech spectrum level.

4.3.2.2 For each calculation band i, determine the value B_i as the larger of the equivalent noise spectrum level, N'_i, or the self-speech masking spectrum level, V_i.

4.3.2.3 For each calculation band, determine the value C_i, the slope per octave of the spread of masking. For the critical band procedure and for the equally-contributing critical band procedure:

$$C_i = -80 + 0.6\,[B_i + 10\lg(h_i - l_i)] \qquad (6)$$

where B_i is the variable calculated in 4.3.2.2, and h_i and l_i are the frequency band higher and lower frequency limits as listed in table 1 or 2.

For one-third octave frequency bands, slope C_i is calculated from:

$$C_i = -80 + 0.6\,[B_i + 10\lg F_i - 6.353] \qquad (7)$$

where B_i is the variable calculated in 4.3.2.2 and F_i is the nominal midband frequency of the one-third octave band as listed in table 3.

4.3.2.4 For the lowest frequency calculation band, the equivalent masking spectrum level, Z_i, is equal to B_i as calculated in 4.3.2.2.

4.3.2.5 For all but the lowest frequency calculation band, determine the equivalent masking spectrum level from equation 8 when using either of the two critical band SII calculation procedures, or equation 9 if using the one-third octave band procedure:

$$Z_i = 10\lg\left\{10^{0.1N'_i} + \sum_{k}^{i-1} 10^{0.1[B_k + 3.32C_k \lg(F_i/h_k)]}\right\} \qquad (8)$$

$$Z_i = 10\lg\left\{10^{0.1N'_i} + \sum_{k}^{i-1} 10^{0.1[B_k + 3.32C_k \lg(0.89F_i/F_k)]}\right\} \qquad (9)$$

where N'_i is equivalent noise spectrum level, B_k is the variable calculated in 4.3.2.2. F_i is the critical band center frequency in tables 1 and 2, or the nominal one-third octave midband frequency in table 3, and h_k is the higher frequency band limit for critical band k (table 1 or 2). For the one-third octave band procedure, F_k is the nominal midband frequency for frequency band k in table 3.

NOTES

1 The summation index, k, for the 21 critical band procedure ranges from band 1 to i−1 = 20 in table 1. For the 17 band equally-contributing critical band procedure the summation runs from computation band 1 to i−1 = 16 in table 2. For the one-third octave band procedure the summation index runs from computation band 1 to i−1 = 17 in table 3.

2 These procedures were developed based on one-third octave spread of masking protocols discussed in reference 10.

4.4 Step 4 — Equivalent internal noise spectrum level, X'_i

Calculate the equivalent internal noise spectrum level (X'_i) by equation 10:

$$X'_i = X_i + T'_i \qquad (10)$$

where X_i is the reference internal noise spectrum level listed in the appropriate table (tables 1-4), and T'_i is the equivalent hearing threshold level determined in 4.2.

4.5 Step 5 — Equivalent disturbance spectrum level, D_i

Determine the disturbance spectrum level, D_i, as the larger of the equivalent masking spectrum level, Z_i, and the equivalent internal noise spectrum level, X'_i.

4.6 Step 6 — Level distortion factor, L_i

Calculate the level distortion factor, L_i, from:

$$L_i = 1 - (E'_i - U_i - 10)/160 \qquad (11)$$

where E'_i is the equivalent speech spectrum level, and U_i is the standard speech spectrum level at the normal vocal effort found in tables 1–4. If the calculated value of the distortion factor exceeds one, the value of one should be used instead.

NOTES

1 This equation has been developed from data given in reference 8. The constant (10) in equation 11 is the difference between 72.35 and the overall level

of standard speech at normal vocal effort. The latter is specified in this standard as 62.35 (e.g., table 1). In the event that revisions of this standard change the values of the speech spectrum for normal vocal effort, the value of the constant (10) will need to be recalculated as 72.35 minus the new overall level of the standard speech spectrum at normal vocal effort.

2 Speech levels causing the distortion factor to become negative are substantially beyond the threshold of pain, and could not occur in practice. Therefore, it is not necessary to limit the value of this factor to positive values only.

4.7 Step 7 — Band audibility function, A_i

4.7.1 Calculate the value of a temporary variable, K_i as:

$$K_i = (E'_i - D_i + 15)/30 \qquad (12)$$

where E'_i and D_i are the equivalent speech spectrum level and the equivalent disturbance level, respectively. The value of K_i must be limited to the interval from 0 to 1, inclusive. That is, if a calculated value is greater than 1, then the value of K_i is set to 1. Similarly, if a calculated value is negative the value of K_i is set to 0.

4.7.2 Calculate the value of the band audibility function as:

$$A_i = L_i K_i \qquad (13)$$

where L_i is the speech level distortion factor, and K_i the value computed in 4.7.1.

4.8 Step 8 — Speech intelligibility index, S

Calculate the speech intelligibility index as:

$$S = \sum_{i=1}^{n} I_i A_i \qquad (14)$$

where I_i is the band importance function, and A_i the band audibility function. The summation is performed over all bands specified for the particular computation procedure being used. In the case of the equally-contributing critical-band procedure the calculations can be simplified, since the band importance function is a constant for all bands:

$$S = 0.0588 \sum_{i=1}^{17} A_i \qquad (15)$$

Example calculations of SII using the octave and one-third octave frequency band procedures are provided in annex C.

5 Methods for determining input variables for SII calculation procedures

SII procedures in clause 4 require that the equivalent speech spectrum level, equivalent noise spectrum level, and the equivalent hearing threshold level be supplied by the user. The details of the procedures for determining these input variables depend on the peculiarities of the communication system and the listener, measurement techniques, available resources, and the required precision. In clauses 5.1–5.3 three protocols, applicable to different communication systems, for determining the equivalent speech, noise, and threshold spectrum levels are provided.

NOTE - It is not intended that the procedures in 5.1–5.3 be the only ones of use for this Standard. The user is encouraged to employ any other technique more appropriate for the particular problem if its validity can be demonstrated. Furthermore, there are communication situations outside the scope of any of the protocols discussed here, for which, therefore, other methods may be necessary. Under any of these circumstances, the user shall state that procedures other than those described in this Standard were used.

Procedures for determination of the equivalent speech and noise spectrum levels (clauses 5.1–5.3) vary with regard to the measurement technique and the physical point at which the intervening variables are measured. With regard to the scope of applications, the most general of the procedures, specified in clause 5.3, requires measurement of the modulation transfer function for intensity, MTFI, and the combined speech and noise spectrum level at the eardrum, CSNSL. Therefore, both the equipment for the MTFI/CSNSL measurement and a human head/ear mannequin are necessary. A less general procedure, discussed in clause 5.2, excludes many communication situations (e.g., telephone links) and requires only the measurement of the MTFI and the CSNSL in a sound field at the position of the listener. The procedure discussed in clause 5.1 requires only the measurement of the noise spectrum level in the absence of speech and an estimation (or measurement) of the speech spectrum level in the absence of noise. However, the field of application of this procedure is even further reduced, because conditions where reverberation decreases speech intelligibility or, more generally, conditions where noise and speech spectrum levels depend on one another are excluded.

5.1 Determination of equivalent speech, noise, and threshold spectrum levels: method based on the direct measurement/ estimation of noise and speech spectrum levels at the listener's position

5.1.1 Necessary conditions. To apply these procedures it is necessary:

(1) to have low reverberant conditions (i.e., conditions where reverberation does not reduce speech intelligibility);

(2) to have the listener facing the talker and the noise source, or to have both speech and noise omnidirectional;

(3) to have conditions in which the speech and noise spectrum do not depend on one another; and

(4) to have either a linear communication system or a system that is linear in the actual mode of operation (e.g., slow acting automatic gain control).

In addition, for binaural listening, if amplification or attenuation devices are worn by the listener, the same amplification or attenuation device must be worn in each ear. Further, for binaural listening, at each frequency, it is required that the average hearing threshold levels for the group of listeners for whom SII calculations are performed be equal in the right and in the left ears.

5.1.2 Applications. These procedures are primarily intended for monaural or binaural communications in relatively free fields or rooms with minimal reverberation. The listener may wear linear attenuation devices (e.g., ear protectors) or linear amplification devices.

5.1.3 Specification of equivalent speech spectrum level. In general, the speech spectrum level can be measured directly at the center of the listener's head (mid-point between the ears; listener absent). However, measurement of a stable and accurate speech spectrum level requires a large number of talkers (at least 20 talkers and 30-second speech samples from each are recommended). Therefore, it is recommended that the standard speech spectrum levels provided in tables 1–4 be used. The tables give the speech spectrum level at 1 m from the talker's lips at various vocal efforts: normal, raised, loud, and shouted.

For some applications, it is more convenient to work with one general form of the speech spectrum level than with the spectrum level whose relative form depends on vocal effort. Sacrificing only little in accuracy, the values for the standard speech spectrum level corresponding to the normal vocal effort can then be employed. For raised, loud, and shouted vocal efforts this spectrum should be increased in steps of 7.8 dB per step of vocal effort. The idealized speech spectrum (see clause 3.10) may also be used, although there are very few reasons, if any, for this within the method discussed in this clause.

NOTE - The value of 7.8 dB has been selected to produce a minimal error in SII and is not equal to the differences in the overall levels of successive vocal efforts. It is equal to the average increase in level across the 17 most important (and equally-contributing) critical bands.

If any of the standard speech spectra are used, the equivalent speech spectrum level, E'_i, for a band i is given as:

$$E'_i = E_i - 20 \lg d/d_0 + G_i \qquad (16)$$

where E_i is the speech spectrum level for band i for the appropriate vocal effort (normal, raised, loud, or shouted), d is the distance in meters from the talker's lips to the center of the listener's head, d_0 is the reference distance of 1 meter, and G_i is the insertion gain.

NOTE - Details of the measurement of the insertion gain are not discussed in this standard. Under most circumstances, these values are either specified by the manufacturer of the devices (e.g., ear protectors) or are determined by the issuer of the device.

If the speech spectrum is directly measured at the center of the listener's head, the equivalent speech spectrum level, E'_i, for a band i is given as:

$$E'_i = E_i + G_i \qquad (17)$$

where E_i is the measured speech spectrum level for band i, and G_i is the insertion gain.

In some applications the overall speech level, rather than spectrum level, is directly measured at the center of the listener's head. Under those circumstances the spectrum level E_i is obtained by adding the difference between the measured overall level and the standard overall level (tables 1–4) to the standard spectrum level found in the same table.

NOTE - As an example, assume that the measured overall sound pressure level is 70 dB at the raised vocal effort. In tables 1–4, the overall SPL which corresponds to the raised vocal effort is 68.34 dB. The difference between the measured overall level and the standard overall level is 70 − 68.34 = 1.66 dB. Consequently, the standard speech spectrum level for raised vocal effort should be increased at each frequency by 1.66 dB to obtain the spectrum level E_i used in equation 17.

5.1.4 Specification of equivalent noise spectrum level. The noise spectrum is generally measured at the center of the listener's head (mid-point between the ears; listener absent). The equivalent noise spectrum level, N'_i) for a band i is given as:

$$N'_i = N_i + G_i \tag{18}$$

where N_i is the measured noise spectrum level for band i, and G_i is the insertion gain.

NOTE - Noise level is usually measured in frequency bands greater than 1 Hz. The band sound pressure levels may be converted to spectrum levels by making the bandwidth adjustment of equation 3. Bandwidth adjustments in decibels for one-third octaves are given in table 3 and in octaves in table 4.

5.1.5 Specification of equivalent hearing threshold level. The scope of this Standard is limited to otologically-normal listeners. For monaural listening, the equivalent hearing threshold level is defined as the arithmetic average of the hearing threshold levels across the group of ears for which SII calculations are performed. For listeners within the age limit of 18-30 years inclusive, the equivalent hearing threshold level is a hearing level of 0 dB across all frequencies. For groups of otologically normal listeners with the hearing threshold level other than average (HL of 0 dB), appropriate values of the equivalent hearing threshold level (i.e., of the average hearing threshold level) should be used. For binaural listening the value of the equivalent hearing threshold level for monaural listening should be decreased by 1.7 dB (reference 11).

NOTE - The equivalent threshold level, being the arithmetic average, rather than a modal value, is not exactly a hearing level of 0 dB. However, this difference is small for all practical considerations.

5.2 Determination of equivalent speech, noise, and threshold spectrum levels: method based on MTFI/CSNSL measurements at the listener's position

5.2.1 Necessary conditions. To apply these procedures for monaural listening it is necessary:

(1) that the listener is located in a well-mixed reverberant speech and noise sound field (the orientation of the listener is irrelevant), or that the listener faces both the dominant speech and noise wave, or that the noise is omnidirectional and that the listener faces the dominant speech wave; and

(2) that the communication system is either linear, or that it can be approximated by a linear system in the actual mode of operation (e.g., slow acting automatic gain control).

In addition, for binaural listening, it is also required:

(3) that, if amplification or attenuation devices are worn by the listener, the same amplification or attenuation device must be worn in each ear; and

(4) that, at each frequency, the average hearing threshold levels for the group of listeners for whom SII calculations are performed be equal in the right and left ears.

5.2.2 Applications. Primary applications of these procedures are communications in reverberant fields or in free fields where the noise level cannot be measured in the absence of speech. The listener may wear amplification or attenuation devices (e.g., hearing protectors) operating in a linear mode.

5.2.3 Specification of equivalent speech and noise spectrum levels. Measurements to determine the apparent speech-to-noise ratio, R, are based on the modulation transfer function methodology developed for the *Speech Transmission Index* (reference 15). Added to these procedures (which were somewhat modified) is the measurement of the combined speech and noise spectrum level, P. Equivalent speech and noise spectra are calculated based on the measured values of R and P.

NOTE - An alternative approach to the measurement procedures of this clause is to obtain the impulse response to the systems (averaging out the noncorrelated noise) and to obtain all other variables by calculations paralleling the discussed measurement procedures. Care should be taken, however, to increase the calculated equivalent noise spectrum level (equation 24) by the measured noncorrelated noise level which was not included in the calculations. The calculated equivalent noise spectrum level and the noncorrelated noise spectrum level should be added to the power basis to obtain the equivalent noise spectrum level. The noncorrelated noise spectrum level is measured as the noise level in the absence of the speech signal. The level, c, of the sum of two levels a and b, (colloquially, the "power" sum) is defined as:

$$c = 10 \lg (10^{0.1a} + 10^{0.1b}) \qquad (19)$$

Care should also be taken that in the case of nonlinear systems which can be approximated by linear ones in the actual mode of operation, the impulse response is obtained on the system properly primed into its actual mode of operation. The computations can be further simplified (reference 14) by calculating the MTFI directly from the squared impulse response g(t):

$$M_{f,i} = \left| \int_0^{\infty} g(t) e^{-j2\pi ft} dt \bigg/ \int_0^{\infty} g(t) dt \right| \qquad (20)$$

5.2.3.1 Provide a test signal which is selected from one of the following three choices:

1) a random noise shaped in such a way that in a free field at a distance of 1 m, in each frequency band i, its spectrum level equals the standard speech spectrum level for the desired vocal effort (tables 1-4, depending on the SII computational procedure).

2) an approximate speech spectrum whose relative form does not depend on the vocal effort. For normal vocal effort, this speech spectrum level is equal to the standard speech spectrum level for normal vocal effort (tables 1-4, depending on the SII computational procedure). For raised, loud, and shouted vocal efforts this spectrum should be increased in steps of 7.8 dB per step of vocal effort.

3) the idealized speech spectrum of the appropriate vocal effort (see clause 3.10) for all four SII computation methods.

NOTE - The value of 7.8 dB has been selected to produce the minimal error in the SII and is not equal to the differences in the overall levels of successive vocal efforts.

On the reference axes, at 0° azimuth and 0° elevation, the sound source should have a directivity index of 1 to 3 dB for frequencies lower than or equal to 1000 Hz, and 2 to 5 dB for frequencies higher than 1000 Hz. The sound source should be mounted in an enclosure with dimensions of the same order as the human head. The frequency response across the SII computational bands should be uniform within ±2 dB.

5.2.3.2 Measurements of speech and noise spectra shall be made at a location corresponding to the center of the listener's head (mid-point between the ears) with the listener absent and with the source at the position of the talker.

5.2.3.3 The test signal shall be sinusoidally modulated in intensity using a modulation index of one, at each of the following nine modulation frequencies (one at a time): 0.5 Hz, 1.0 Hz, 1.5 Hz, 2.0 Hz, 3.0 Hz, 4.0 Hz, 6.0 Hz, 8.0 Hz, and 16.0 Hz. Sinusoidal modulation in intensity is realized by multiplying the test signal by $1.414\cos\pi ft$, where f is the modulation frequency.

NOTE - Multiplying the signal by $1.414\cos\pi ft$ is equivalent to multiplying the squared signal by $1 + \cos 2\pi ft$.

5.2.3.4 For each modulation frequency f, analyze a measure of the square of the received signal in each frequency band i (signal components outside the frequency band i are filtered out before squaring), and determine the modulation index of this waveform. This index represents the value of the modulation transfer function, $M_{f,i}$, for intensity for the modulation frequency f and the band i. The analysis time should be long enough (typically eight periods of the modulation frequency) to obtain a stable estimate of the modulation index. Considering that the input signal is a random noise it is possible that in some practical realizations and for some averaging times even under ideal listening circumstances a reduction of the modulation index to values lower than one is observed. Therefore, a careful calibration of the measuring system under ideal circumstances is required. The actual modulation transfer function for intensity $M_{f,i}$ is equal to the measured modulation transfer functions for intensity divided by the modulation transfer function for intensity under the ideal circumstances observed over the same averaging time.

NOTE - One of the ways to perform the measurements, for a given modulation frequency, is as follows:

(1) A sample of the received modulated signal is stored in a computer. The sample should be sufficiently long to enable stable estimates of the variables discussed below (typically eight periods of the modulation frequency).

(2) For each calculation band i, the following is performed:

(a) The signal is band-pass filtered with a filter having cutoff frequencies equal to the low and high limits of the band i. For critical band procedures, these limiting frequencies are given in tables 1 and 2. For the 1/3-octave procedure and the octave procedure, respectively, 1/3-octave filters and octave filters are used, centered at the center frequency of a given calculation band (tables 3 and 4).

(b) The signal is then squared.

(c) After squaring, the signal is low-pass filtered. The cutoff frequency should be slightly higher than the modulation frequency (e.g., 10% higher) and care should be taken that 0 Hz (dc) is not eliminated in the process. This waveform, i.e., the intensity envelope for the band i of the received signal, will be labeled as $I(t)$.

(d) The mean value γ of $I(t)$ is obtained over a sufficiently large number of modulation periods to provide for a stable estimate.

(e) Waveform $I(t)$ is multiplied by $\cos 2\pi ft$, where f is the modulation frequency, and the mean value, α, of the resultant waveform is obtained over a sufficiently large number of modulation periods to provide for a stable estimate.

(f) Waveform $I(t)$ is multiplied by $\sin 2\pi ft$, where f is the modulation frequency, and the mean value, β, of the resultant waveform is obtained over a sufficiently large number of modulation periods to provide for a stable estimate.

(g) The modulation transfer function for intensity for modulation frequency f and the calculation band i, $M_{f,i}$, is then calculated as:

$$M_{f,i} = 2(\alpha^2 + \beta^2)^{1/2}/\gamma \qquad (21)$$

5.2.3.5 Calculate the apparent speech-to-noise ratio, in decibels, for each modulation frequency f and each band i:

$$R_{f,i} = 10\,\lg[M_{f,i}/(1-M_{f,i})] \qquad (22)$$

The value of $R_{f,i}$ should be limited to the interval −15, +15 dB. That is, if the calculated value is smaller than −15, the value of −15 dB should be used. Likewise, if the calculated value is larger than 15, the value of 15 dB should be used.

5.2.3.6 Determine the average apparent speech-to-noise ratio for each SII band i, R_i, by averaging the values of $R_{f,i}$ across nine modulation frequencies f (0.5 Hz to 16 Hz).

5.2.3.7 Measure, without any modulation, for each band i, the spectrum level of the received signal P_i. This is the combined speech and noise spectrum level (CSNSL).

NOTE - A properly calibrated system can use the already measured value, γ (See note in clause 5.2.3.4).

5.2.3.8 Calculate the equivalent speech spectrum level E'_i and the equivalent noise spectrum level N'_i for band i:

$$E'_i = R_i + 10\,\lg[10^{0.1P_i}/(1+10^{0.1R_i})] \qquad (23)$$

$$N'_i = E'_i - R_i \qquad (24)$$

5.2.4 Specification of equivalent hearing threshold level. The scope of this standard is limited to otologically-normal listeners. For monaural listening, the equivalent hearing threshold level is defined as the arithmetic average of the hearing threshold levels across the group of ears for which SII calculations are performed. For listeners within the age limit of 18–30 years inclusive, the equivalent hearing threshold level is, therefore, a hearing level of 0 dB across all frequencies.

For groups of otologically normal listeners with the hearing threshold level other than average (HL of 0 dB), appropriate values of the equivalent hearing threshold level (i.e., of the average hearing threshold level) should be used. For binaural listening the value of the equivalent hearing threshold level for monaural listening should be decreased by 1.7 dB (reference 11).

5.3 Determination of equivalent speech, noise, and threshold spectrum levels: method based on MTFI/CSNSL measurements at the eardrum of the listener

5.3.1 Necessary conditions. For monaural listening, it is required that:

1) the communication system is either linear, or that it can be approximated by a linear system in the actual mode of operation (e.g., slow acting automatic gain control).

2) for binaural listening it is also necessary that, at each frequency, neither the speech spectrum level nor the noise spectrum level differ (either in amplitude or in phase) in the right and the left ears of the listener.

3) further, for binaural listening, it is required that, at each frequency, the average hearing threshold levels for the group of listeners for whom SII calculations are performed be equal in the right and left ears (within 5 dB).

5.3.2 Applications. The primary applications of these procedures are communication circumstances that do not satisfy the necessary conditions of clauses 5.1 and 5.2.

5.3.3 Specification of equivalent speech and noise spectrum levels. The methods of this clause are exactly the same as those of 5.2.3, with three exceptions:

1) the location for measurements of speech and noise spectra;

2) the spectrum levels obtained by applying equations 23 and 24 are termed *apparent* speech and noise spectrum levels; and

3) the apparent speech and noise spectrum levels are adjusted to equivalent speech and noise spectrum levels by applying the free-field to eardrum transfer function in an additional step in the procedure.

Specifically, the procedures of 5.2.3 apply to the procedures of 5.3.3 with the following changes:

5.3.3.2 Measurements of speech and noise spectra shall be made at the equivalent of the eardrum of the listener by using a human head and torso simulator designed for measurement of acoustic pressure at the eardrum.

NOTE - For many applications the device described in ANSI S3.35-1985 (R 1997) is adequate. Alternatively, measurements could be performed on a large number of ears of otologically normal subjects within the age limit 18–30 years inclusive, using a probe tube microphone located no more than 5 mm from the eardrum. No fewer than eight ears of eight different individuals should be used.

5.3.3.3 Calculate the apparent speech spectrum level E_i and the apparent noise spectrum level N_i for band i:

$$E_i = R_i + 10 \lg [10^{0.1P_i}/(1 + 10^{0.1R_i})] \quad (25)$$

$$N_i = E_i - R_i \quad (26)$$

5.3.3.4 *Calculate the equivalent speech spectrum level* E'_i and the equivalent noise spectrum level N_i for band i:

$$E'_i = E_i - H_i \quad (27)$$

$$N'_i = N_i - H_i \quad (28)$$

where H_i is the free-field to eardrum transfer function for calculation band i as listed in tables 1–4.

5.3.4 Specification of equivalent hearing threshold level. See 5.2.4.

6 General relation between the intelligibility of received speech and the Speech Intelligibility Index

The intelligibility of received speech depends not only on the SII but also on other factors, such as the nature of the message being transmitted (e.g., its syntactic, semantic, linguistic, and contextual constraints) and the proficiency of the listeners and talkers. In annex B a means of predicting speech intelligibility based on the SII and the nature of the message is provided. However, for communication systems where the nature of the message and proficiency of the listeners and talkers may vary greatly from one moment to another, *the intelligibility of speech also varies greatly. For* such general conditions, the SII, calculated with the importance function for average speech used in this standard, is a better descriptor of the quality of the communication system with respect to intelligibility than any SII calculated with a different importance function.

The value of SII required for a given communication system is, of course, dependent upon factors whose importance can be evaluated only by the users of the system. Approximately, however, *good communication systems have an SII in excess* of 0.75, while poor communication systems have an SII below 0.45.

Annex A
(normative)
SII for individuals with hearing loss

A.1 Scope

This annex extends the methods of the basic SII standard to include the average effects of elevated hearing threshold levels.

A.2 Purpose

Although the equivalent hearing threshold level is one of the input variables of the SII protocol, the scope of the SII standard is limited to otologically normal listeners. The reason for this is that some hearing pathologies may have effects on speech intelligibility above that predicted based on the hearing threshold level alone. Various procedures have been proposed for correcting the SII protocol to include these *suprathreshold deficits* (references A1, A2, and A4). However, because the existence of suprathreshold deficit has not been sufficiently documented (reference A3), this annex provides a method for calculating SII which includes only the effect of an elevated hearing threshold level.

A.3 Applications

The SII, as calculated in this annex, represents the average performance characteristic of a group of individuals with the same audiogram and no suprathreshold deficits. It provides an insight into the effects of the given hearing threshold elevation, per se, on speech intelligibility. Therefore, the procedures apply to all hearing pathologies, but account only for the effects of hearing threshold loss.

A.4 Definitions

A.4.1 conductive hearing loss. Impairment of hearing that occurs when there is interference with the transmission of sound waves through the external and/or middle ears.

A.5 Calculations

In general, calculation and measurement details are the same as those specified in clauses 4 and 5. The only modification concerns the calculation of the speech level distortion factor, L_i, specified in 4.6. Equation 11 of 4.6 should be modified to include an additional loss factor, J_i, where J_i is the part of the equivalent hearing threshold level due to the presence of the conductive hearing loss (conductive hearing loss component):

$$L_i = 1 - (E'_i - U_i - 10 - J_i)/160. \quad \text{(A1)}$$

E'_i is the equivalent speech spectrum level, and U_i is the standard speech spectrum level at the normal vocal effort found in tables 1–4. If the calculated value of the distortion factor exceeds one, the value of one should be used instead.

A.6 References

[A.1] Leijon, A. (1990) "Hearing aid gain for loudness-density normalization in cochlear hearing losses with impaired frequency resolution," *Ear Hear.* **12**, 242-250.

[A.2] Ludvigson, C. (1987) "Prediction of speech intelligibility for normal-hearing and cochlearly hearing-impaired listeners," *J. Acoust. Soc. Am.* **82**, 1162-1170.

[A.3] Pavlovic, C.V. (1993) "Problems in the prediction of speech recognition performance of normal-hearing and hearing-impaired individuals," In Studebaker, G.A. and Hochberg, I. (eds.), *Acoustical factors affecting hearing aid performance*, 2nd edition, Allyn and Bacon, Needham Heights, MA.

[A.4] Pavlovic, C.V., Studebaker, G.A., Sherbecoe, R.L. (1986) "An articulation index based procedure for predicting the speech recognition performance of hearing-impaired individuals," *J. Acoust. Soc. Am.* **80**, 50-57.

Annex B
(informative)
Transferring SII to speech intelligibility

The speech intelligibility score, a means for quantifying the quality of a speech environment, is a monotonically increasing function of the Speech Intelligibility Index. The exact form of this function (i.e., transfer function) depends on the nature of the message being transmitted (e.g., its syntactic,

Table B.1 — Critical band importance functions for various speech tests.

Band No.	Center Freq, Hz	NNS[a]	CID-22[b]	NU6[c]	DRT[d]	Short Passages[e]	SPIN[f]
1	150	0.0000	0.0507	0.0234	0.0122	0.0192	0.0130
2	250	0.0230	0.0677	0.0368	0.0553	0.0312	0.0478
3	350	0.0385	0.0641	0.0520	0.0581	0.0926	0.0451
4	450	0.0410	0.0552	0.0672	0.0672	0.1031	0.0470
5	570	0.0433	0.0474	0.0638	0.0680	0.0735	0.0523
6	700	0.0472	0.0468	0.0566	0.0667	0.0611	0.0591
7	840	0.0473	0.0466	0.0503	0.0587	0.0495	0.0591
8	1000	0.0470	0.0502	0.0465	0.0547	0.0440	0.0503
9	1170	0.0517	0.0586	0.0539	0.0563	0.0440	0.0503
10	1370	0.0537	0.0591	0.0576	0.0575	0.0490	0.0556
11	1600	0.0582	0.0586	0.0642	0.0625	0.0486	0.0699
12	1850	0.0679	0.0609	0.0741	0.0598	0.0493	0.0625
13	2150	0.0745	0.0596	0.0709	0.0555	0.0490	0.0602
14	2500	0.0750	0.0618	0.0621	0.0521	0.0547	0.0684
15	2900	0.0685	0.0501	0.0553	0.0480	0.0555	0.0638
16	3400	0.0662	0.0439	0.0505	0.0443	0.0493	0.0605
17	4000	0.0636	0.0370	0.0417	0.0356	0.0359	0.0534
18	4800	0.0607	0.0268	0.0291	0.0280	0.0387	0.0394
19	5800	0.0511	0.0201	0.0186	0.0237	0.0256	0.0291
20	7000	0.0216	0.0186	0.0141	0.0205	0.0219	0.0132
21	8500	0.0000	0.0162	0.0113	0.0153	0.0043	0.0000

[a]NNS (various nonsense syllable tests where most of the English phonemes occur equally often), [b]CID-W22 (PB-words), [c]NU6 monosyllables, [d]DRT (Diagnostic Rhyme Test), [e]short passages of easy reading material, [f]SPIN monosyllables

semantic, linguistic, and contextual constraints) and on the proficiency of the talkers and listeners. The transfer function should be developed by the user for the type of speech material whose intelligibility needs to be predicted and by employing listeners and talkers whose expertise samples adequately the population that will be using the systems.

In addition, for higher accuracy, the SII should be calculated using the importance function characteristic of the actual speech material that is employed. This, however, is not necessary in conditions where the equivalent noise spectrum level and the equivalent speech spectrum level are roughly parallel. Tables B.1, B.2, and B.3 give the importance functions of various types of speech material for, respectively, the critical band procedure, the 1/3-octave band procedure, and the octave band procedure. Included are the importance functions for:

(1) Nonsense syllable tests of CV (consonant-vowel), VC (vowel-consonant), and CVC (consonant-vowel-consonant) type where most of the English phonemes occur equally often.

NOTE - For the derivation of this importance function see reference B.6. It is appropriate for a number of CVC, CV, or VC speech tests when a group of talkers is used (e.g., Bell Laboratories tests, reference B.5), or for the original recording of the Memphis Nonsense Syllable Test (MNST) (reference B.11).

(2) Phonetically-balanced words of the CID-W22 test.

NOTE - For the test description see reference B.8. The importance function was developed for the recording by Technisonic Studios (reference B.13).

(3) Monosyllables of the NU6 test.

NOTE - For the test description see reference B.16. For the derivation of the importance function see ref-

Table B.2 — One-third octave band importance functions for various speech tests.

Band No.	Midband Freq, Hz	NNS[a]	CID-22[b]	NU6[c]	DRT[d]	Short Passages[e]	SPIN[f]
1	160	0.0000	0.0365	0.0168	0.0000	0.0114	0.0000
2	200	0.0000	0.0279	0.0130	0.0240	0.0153	0.0255
3	250	0.0153	0.0405	0.0211	0.0330	0.0179	0.0256
4	315	0.0284	0.0500	0.0344	0.0390	0.0558	0.0360
5	400	0.0363	0.0530	0.0517	0.0571	0.0898	0.0362
6	500	0.0422	0.0518	0.0737	0.0691	0.0944	0.0514
7	630	0.0509	0.0514	0.0658	0.0781	0.0709	0.0616
8	800	0.0584	0.0575	0.0644	0.0751	0.0660	0.0770
9	1000	0.0667	0.0717	0.0664	0.0781	0.0628	0.0718
10	1250	0.0774	0.0873	0.0802	0.0811	0.0672	0.0718
11	1600	0.0893	0.0902	0.0987	0.0961	0.0747	0.1075
12	2000	0.1104	0.0938	0.1171	0.0901	0.0755	0.0921
13	2500	0.1120	0.0928	0.0932	0.0781	0.0820	0.1026
14	3150	0.0981	0.0678	0.0783	0.0691	0.0808	0.0922
15	4000	0.0867	0.0498	0.0562	0.0480	0.0483	0.0719
16	5000	0.0728	0.0312	0.0337	0.0330	0.0453	0.0461
17	6300	0.0551	0.0215	0.0177	0.0270	0.0274	0.0306
18	8000	0.0000	0.0253	0.0176	0.0240	0.0145	0.0000

[a]NNS (various nonsense syllable tests where most of the English phonemes occur equally often), [b]CID-W22 (PB-words), [c]NU6 monosyllables, [d]DRT (Diagnostic Rhyme Test), [e]short passages of easy reading material, [f]SPIN monosyllables

erence B.14. The importance function is appropriate for the original recording of the test.

(4) Words of the two alternative Diagnostic Rhyme Test (DRT) material.

NOTE - For the test description see reference B.17. For the derivation of the importance function see reference B.4. The importance function is appropriate for the original recording of the test.

(5) Short passages of easy reading material.

NOTE - For the test description see reference B.3. For the derivation of the importance function see reference B.12. This importance function is also known

Table B.3 — Octave band importance functions for various speech tests.

Band No.	Midband Freq, Hz	NNS[a]	CID-22[b]	NU6[c]	DRT[d]	Short Passages[e]	SPIN[f]
1	250	0.0437	0.1549	0.0853	0.0960	0.1004	0.0871
2	500	0.1294	0.1562	0.1912	0.2043	0.2551	0.1493
3	1000	0.2025	0.2165	0.2110	0.2343	0.1960	0.2206
4	2000	0.3117	0.2768	0.3090	0.2643	0.2322	0.3022
5	4000	0.2576	0.1488	0.1682	0.1501	0.1744	0.2102
6	8000	0.0551	0.0468	0.0353	0.0510	0.0419	0.0306

[a]NNS (various nonsense syllable tests where most of the English phonemes occur equally often), [b]CID-W22 (PB-words), [c]NU6 monosyllables, [d]DRT (Diagnostic Rhyme Test), [e]short passages of easy reading material, [f]SPIN monosyllables

as the importance function for *continuous discourse* (reference B.12) or as the importance function for *easy speech* (reference B.10).

(6) Monosyllables of the Speech in the Presence of Noise (SPIN) test.

NOTE - This importance function was derived from the data reported in reference B.1 for the revised version of the SPIN test (reference B.2). It should also be appropriate for any other version of the SPIN test based on the speech material extracted from the Bolt, Beranek and Newman recording, including the original version of the test (reference B.9). This importance function is appropriate for both "high predictability" (PH) and "low predictability" (PL) items of the test, as well as for the mean scored based on both types of items.

B.1 Visual cues

Visual cues from observing the talker's lips or face contribute to the intelligibility of speech. Therefore, transfer functions and importance functions developed for audio-only speech, cannot be used. For each specific audio-visual communication setting an appropriate transfer function and an appropriate importance function need to be developed. An alternative, but approximate, solution for connected speech is to use the importance function and the transfer function for audio-only speech but predict the score based on the *audio-visual* SII. The following equation can be used for calculating the audio-visual SII (S_{av}) from the normally (audio only) computed SII (S) in the case of listeners not specially trained in *speech reading*, and under conditions of good visibility of visual cues (adapted from references B.7 and B.16):

$$S_{av} = b + cS \qquad \text{(B1)}$$

where b and c are constants. For S not greater than 0.2, b and c are, respectively, 0.1 and 1.5. For S greater than 0.2, b and c are, respectively, 0.25 and 0.75.

NOTE - In general, the benefit provided by visual cues is inversely proportional to the degree of redundancy between the visual and auditory conditions. For consonant or vowel recognition, a measure of redundancy can be determined from the specific error patterns for individual speech elements presented under auditory and visual conditions.

B.2 References

[B.1] Bell, S.T., Dirks, D.D., and Trine, T.D. (1992) "Frequency-importance functions for words in high- and low-context sentences," *J. Speech Hear. Res.* **35**, 950-959.

[B.2] Bilger, R.C., Nuetzel, J.M., Rabinowitz, W.M., and Rzeczkowski, C. (1984) "Standardization of a test of speech perception in noise," *J. Speech Hear. Res.* **27**, 32-48.

[B.3] Cox, R.M. and McDaniel, D.M. (1984) "Intelligibility rating of continuous discourse: application to hearing aid selection," *J. Acoust. Soc. Am.* **76**, 758-766.

[B.4] Duggirala, V., Studebaker, G.A., Pavlovic, C.V., and Sherbecoe, R.L. (1988) "Frequency importance functions for a feature recognition test material," *J. Acoust. Soc. Am.* **83**, 2372–2382.

[B.5] Fletcher, H. and Steinberg, J.C. (1929) "Articulation testing methods," *Bell Sys. Tech. J.*, **8**, 806-854.

[B.6] French, N.R. and Steinberg, J.C. (1947) "Factors governing the intelligibility of speech sounds," *J. Acoust. Soc. Am.* **19**, 90-119.

[B.7] Grant, K.W. and Braida, L.D. (1991) "Evaluating the articulation index for auditory-visual input," *J. Acoust. Soc. Am.* **89**, 2952–2960.

[B.8] Hirsh, I.J., Davis, H., Silverman, S.R., Reynolds, E.G., Eldert, E., and Benson, R.W. (1952) "Development of materials for speech audiometry," *J. Speech Hear. Dis.* **15**, 321-337.

[B.9] Kalikow, D.N., Stevens, K.N., and Eliott, L.L. (1977) "Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability," *J. Acoust. Soc. Am.* **61**, 1337-1351.

[B.10] Pavlovic, C.V. (1987) "Derivation of primary parameters and procedures for use in speech intelligibility predictions," *J. Acoust. Soc. Am.* 82, 413-422.

[B.11] Pavlovic, C.V. and Studebaker, G.A. (1984) "An evaluation of some assumptions underlying the articulation index," *J. Acoust. Soc. Am.* **75**, 1606-1612.

[B.12] Studebaker, G.A., Pavlovic, C.V., and Sherbecoe, R.L. (1987) "A frequency importance function for continuous discourse," *J . Acoust. Soc. Am.* **81**, 1130-1138.

[B.13] Studebaker, G.A. and Sherbecoe, R.L. (1991) "Frequency-importance and transfer functions for recorded CID W-22 word lists," *J. Speech Hear. Res.* 34, 427-438.

[B.14] Studebaker, G.A., Sherbecoe, R.L., and Gilmore, C. (1993) "Frequency-importance and transfer functions for the Auditec of Saint Louis recording of the NU-6 word test," *J .Speech Hear. Res.* **36**, 799-807.

[B.15] Sumby, W.H. and Pollack, I. (1954) "Visual contribution to speech intelligibility in noise," *J. Acoust. Soc. Am.* **26**, 212-215.

[B.16] Tillman, T.W. and Carhart, R. (1981) "An expanded test for speech discrimination utilizing CNC monosyllabic words: Northwestern University Auditory Test No. 6," In Chaiklin, J.B., Ventry, I.M., & Dixon, R.F. (eds.), *Hearing measurement; a book of readings, 2nd edition*, Addison Wesley, Reading, Mass.

[B.17] Voiers, W.D. (1983) "Evaluating processed speech using the diagnostic rhyme test," *Speech Tech.* **1**, 30-39.

Annex C
(informative)
Examples of SII computations

C.1 Example: Octave band procedure

An example of the calculation of the SII using the octave band procedure is shown in table C.1. Except for STEP 3, the critical band and one-third octave band the procedures parallel closely the octave band method illustrated in this example.

Step 1: Band numbers, i, and the midband frequencies of the octave bands, F_i, which are listed in table 4, are entered in table C.1.

Step 2: The equivalent speech E'_i, noise N'_i, and hearing threshold T'_i spectrum levels are supplied by the user for the application at hand. The values listed in table C.1 are only examples. Normally, these values are determined either using methods specified in clause 5, or other appropriate and validated means.

Step 3: For the octave band procedure, the equivalent masking spectrum level Z_i is equal to the equivalent noise spectrum level N'_i.

Step 4: The values for the reference internal noise spectrum level, X_i, also listed in table 4, are entered in table C.1. The equivalent internal noise spectrum level, X'_i, is calculated using equation 10.

Step 5: The equivalent disturbance spectrum level, D_i, is the larger of the equivalent masking spectrum level, Z_i, and the equivalent internal noise spectrum level, X'_i.

Step 6: The standard speech spectrum level at the normal vocal effort, U_i, is obtained from table 4 and the speech level distortion factor L_i is calculated using equation 11 (limited to the maximum value of 1.0).

Step 7: Values K_i are calculated using equation 12 (limited to the interval from 0.0 to 1.0) and the values of the band audibility function, A_i, are obtained using equation 13.

Step 8: The values of the band importance function, I_i, listed in table 4, are entered in table C.1 and are multiplied by their respective A_i values. Finally, these products, $I_i A_i$, are summed over all bands i to obtain SII. The result for this example is SII = 0.504.

Table C.1 — Worksheet for octave band SII calculation example.

Step 1		Step 2			Step 3	Step 4		Step 5	Step 6		Step 7		Step 8	
i	F_i	E'_i	N'_i	T'_i	Z_i	X_i	X'_i	D_i	U_i	L_i	K_i	A_i	I_i	I_iA_i
1	250	50.0	70.0	0.0	70.0	-3.9	-3.9	70.0	34.75	0.97	0.00	0.00	0.06	0.00
2	500	40.0	65.0	0.0	65.0	-9.7	-9.7	65.0	34.27	1.00	0.00	0.00	0.17	0.00
3	1000	40.0	45.0	0.0	45.0	-12.5	-12.5	45.0	25.01	0.97	0.33	0.32	0.24	0.08
4	2000	30.0	25.0	0.0	25.0	-17.7	-17.7	25.0	17.32	0.98	0.67	0.66	0.27	0.17
5	4000	20.0	1.0	0.0	1.0	-25.9	-25.9	1.0	9.33	0.10	1.00	0.10	0.21	0.21
6	8000	0.0	-15.0	0.0	-15.0	-7.1	-7.1	-7.1	1.13	1.00	0.74	0.73	0.05	0.04
														SII=0.50

Table C.2 — Worksheet for one-third octave band SII calculation example.

Step 1		Step 2			Step 3			
i	F_i	E'_i	N'_i	T'_i	V_i	B_i	C_i	Z'_i
1	160	54.00	40.00	0.00	30.00	40.00	-45.59	40.00
2	200	54.00	30.00	0.00	30.00	30.00	-52.01	34.66
3	250	54.00	20.00	0.00	30.00	30.00	-51.42	25.04

C.2 Example: One-third octave band procedure

The procedures for the critical band procedure, equally-contributing critical band procedure, and one-third octave band procedure are more complex than those of the octave band procedure reported in C.1 and typically necessitate an appropriate computer algorithm, particularly because of the calculations of the equivalent masking spectrum in Step 3, clause 4.3. An example of these calculations, for the first three one-third octave bands, is summarized in table C.2.

The calculations for the critical band procedure and the equally-contributing critical band procedure are similar to those for the one-third octave band procedure (equations 7 and 9 are used for the one-third octave band procedure, while equations 6 and 8 are used for the critical band procedure and the equally-contributing critical band procedure).

Step 1: Band numbers, i, and the nominal mid-band frequency of the one-third octave bands, F_i, listed in table 3, are entered in table C.2.

Step 2: The equivalent speech, E'_i, noise, N'_i, and hearing threshold, T'_i, spectrum levels are supplied by the user for the application at hand. The values listed in table C.2 are only examples.

Step 3a: The self-speech masking spectrum level, V_i, is calculated using equation 5.

Step 3b: Values B_i are calculated as the larger of the equivalent noise spectrum level, N'_i, or the self-speech masking spectrum level, V_i.

Step 3c: The slope per octave, C_i, of the spread of masking due to band i is calculated using equation 7. For example, for band #1:

$$C_1 = -80 + 0.6\,[B_1 + 10\lg F_1 - 6.353]$$

$$C_1 = -80 + 0.6\,[40 + 10\lg(160) - 6.353]$$

$$= -46.59$$

Step 3d: For band #1, the equivalent masking spectrum level, Z_1, is equal to the equivalent noise spectrum level, N'_1.

Step 3e: For other than band #1, the equivalent masking spectrum level, Z_i, is calculated using equation 9. For any given band, i, there are i addends within the brackets of this equation. While the first of the addends represents the masking in band i due to the noise in the same band ("in-band masking"), the other i - 1 addends represent masking in band i due to the lower i - 1 bands ("spread of masking"). For example, for band #3, there would be three addends, one for the in-band masking, one for the spread of masking from band #1 to band #3, and one for spread of masking from band #2 to band #3. Restating equation 9:

$$Z_i = 10\lg\left\{10^{0.1N'_i} + \sum_{k}^{i-1} 10^{0.1[B_k + 3.32C_k \lg(0.89F_i/F_k)]}\right\} \quad (9)$$

in symbols, the first terms for i = 3 become:

$$Z_3 = 10\lg\{10^{0.1N'_3} + 10^{0.1[B_1 + 3.32C_1\lg(0.89F_3/F_1)]} + 10^{0.1[B_2 + 3.32C_2\lg(0.89F_3/F_2)]}\}$$

or,

$$Z_3 = 10\lg\{10^{0.1(20)} + 10^{0.1[40+3.32*(-46.59)\lg(0.89(250/160))]} + 10^{0.1[30+3.32*(-52.01)\lg(0.89(250/200))]}\}$$

$$Z_3 = 25.04 \text{ dB.}$$

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- **ANSI S1.4A-1985** Amendment to S1.4-1983
- **ANSI S1.6-1984 (R 1997)** American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements
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S2 STANDARDS ON MECHANICAL VIBRATION AND SHOCK

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