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Road vehicles — Ergonomic aspects of transport information and control systems — Specifications for in-vehicle auditory presentation (ISO 15006:2011)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee AUE/12, Safety related to occupants.

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Straßenfahrzeuge - Ergonomische Aspekte von Verkehrsinformations- und Assistenzsystemen - Anforderungen und Konformitätsverfahren für die Ausgabe auditiver Informationen im Fahrzeug (ISO 15006:2011)

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Foreword

This document (EN ISO 15006:2011) has been prepared by Technical Committee ISO/TC 22 "Road vehicles" in collaboration with Technical Committee CEN/TC 278 “Road transport and traffic telematics” the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2012, and conflicting national standards shall be withdrawn at the latest by April 2012.

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Endorsement notice

The text of ISO 15006:2011 has been approved by CEN as a EN ISO 15006:2011 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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ISO 15006 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics applicable to road vehicles*.

This second edition cancels and replaces the first edition (ISO 15006:2004), which has been technically revised.

Introduction

The driver and the vehicle are an integrated system that includes the environment, the primary vehicle controls, the instrumentation, and the transport information and control systems (TICS). The driving task, and human capabilities and limitations, are other primary factors. TICS are intended to support the driver's primary task, and therefore it is expected that the overall workload of the driver will not be negatively influenced, while performance and comfort should be increased.

The multitude of information to be displayed to the driver through TICS may create the need to minimize visual load and make more and better use of the auditory channel. This International Standard provides ergonomic specifications for the design and installation of auditory displays presenting speech and tonal information while driving. The aim of these specifications is to help designers to provide auditory signals which meet usability, comfort and safety criteria.

Road vehicles — Ergonomic aspects of transport information and control systems — Specifications for in-vehicle auditory presentation

1 Scope

This International Standard establishes ergonomic specifications for the presentation of auditory information related to transport information and control systems (TICS) through speech or sounds. It applies primarily to the use of auditory displays to the driver when the vehicle is in motion, but it may also be applied when the vehicle is stationary. It presents a set of requirements and recommendations for in-vehicle auditory signals from TICS, and provides characteristics and functional factors for maximizing auditory signal intelligibility and utility while helping prevent auditory or mental overload.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 532, *Acoustics — Method for calculating loudness level* [1)]

ISO 5128:1980, *Acoustics — Measurement of noise inside motor vehicles*

ISO/TS 16951, *Road vehicles — Ergonomic aspects of transport information and control systems (TICS) — Procedures for determining priority of on-board messages presented to drivers*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
ambient auditory noise
auditory sensory stimulus bearing no informational relationship to the presence or completion on the immediate task that surrounds the driver in the vehicle's environment, including sound emanating from inside and outside the vehicle

3.2
audibility
degree to which an auditory signal can be heard by a person with normal hearing

3.3
auditory icon
auditory signal that represents an event or action

NOTE This auditory signal can be a synthesized sound that gives the impression of specific event or a recorded sound from everyday life.

3.4
auditory signal
tone or verbal cues emitted by an in-vehicle device, which provide information to the driver or passengers

1) The German standard DIN 45631 is largely identical to ISO 532. In practice, references for calculating loudness according to ISO 532 usually implement the code given in DIN 45631 [8].

3.5
broadband signal
complex sound whose acoustical energy is distributed over a wide range of frequencies

3.6
comprehensibility
characteristic of an auditory signal that enables the driver to understand its meaning in the context in which it is provided

3.7
diffuse field
sound field in which the sound pressure level is the same everywhere and the flow of energy is equally probable in all directions

3.8
distinguishability
characteristic of an auditory signal enabling the driver to perceive the differences between it and other audible signals within the driving environment

NOTE Other audible signals include warning signals and signal noise, but exclude ambient noise.

3.9
free field
sound field with no reflective surfaces over the frequency range of interest

3.10
loudness
sensation (perception) that is most closely related to the sound amplitude of an acoustical stimulus

NOTE In this International Standard, loudness is expressed in units of sones.

3.11
main audible component
tonal component with the most energy in the auditory signal

3.12
narrowband signal
sound whose acoustical energy is distributed over a narrow range of frequencies

3.13
narrowband spectrum
spectrum with a frequency resolution of 10 Hz or less

3.14
safety criticality
severity of the likely event that can occur if the driver is unable to avoid a specific hazard

NOTE Four levels of criticality, based on occupant (or other road user) injury and vehicle damage, are defined by ISO/TS 16951.

3.15
safety warning
auditory signal that is intended to prevent or mitigate injuries or vehicle damage

NOTE Navigation and route guidance instructions are not safety warnings even though they might also require the driver to take an action within a short time period.

3.16
signal-to-noise ratio
SNR
ratio of signal specific loudness spectrum to noise specific loudness spectrum

3.17
sone
subjective unit of loudness, as perceived by a person with normal hearing, equal to the loudness of a 1 000 Hz pure tone presented frontally with a sound pressure level of 40 dB, re 20 µPa.

NOTE 1 When measured in a free field, this definition for sone is sometimes designated as sone GF. For a diffuse (rather than free) field, the designation is sone GD. A vehicle interior may be characterized as free field or diffuse field depending on the location (e.g. instrument cluster, audio system speakers, turbulent noise on the windshield) and type of sound (e.g. chime, road noise, and wind noise).

NOTE 2 The loudness of a sound that is judged by a listener to be *n* times that of a 1-sone tone is *n* sones.

3.18
sound pressure level
SPL
local pressure deviation from the ambient pressure caused by a sound

3.19
specific loudness spectrum
distribution of loudness over the frequency axis

3.20
time-critical signal
auditory signal that requires a driver response to an imminent event measurable within a limited number of seconds

NOTE The signal may or may not pertain to a warning event.

3.21
tonal signal
simple sound or mixture of simple sounds with fixed frequency content

NOTE 1 A simple sound is a sinusoidal signal with fixed or single frequency content.

NOTE 2 A tonal signal can be a continuous sound or intermittent sound.

3.22
unit of information
individual or group of auditory signals regarded as a structural or functional constituent of a message

4 Signal specifications

4.1 Spectrum

4.1.1 General

The recommended frequency range for in-vehicle auditory signals is 200 Hz to 8 000 Hz.

4.1.2 Tonal signals

For tonal signals, the main audible component should lie between 400 Hz and 2 000 Hz to protect against decreased audibility due to age-related hearing loss [22].

A broadband signal or a mix of narrowband signals with distinctly separated centre frequencies should be used to improve the signal location detection and driver attention direction.

EXAMPLE A mix of two narrowband signals, with the main audible component centred around 800 Hz, and the other component centred around 3 000 Hz.

The urgency of a situation should be reflected by the character of the signal.

4.2 Signal levels

4.2.1 General

The selection of optimal sound amplitude is a matter of balancing listener comfort against signal audibility. The latter is primarily a function of the signal-to-noise ratio (SNR) between the auditory signal and the ambient auditory noise. It should be kept in mind that loudness depends on the level of the ambient auditory noise and on the level of the auditory signal within a given frequency band. Therefore, loudness at a given SNR increases with rising ambient auditory noise.

4.2.2 Measuring sound loudness

The method for measuring and evaluating the loudness of auditory signals shall be as described in Annex A. Specific details of the method are given in DIN 45631 [7].

This International Standard deals only with the loudness of stationary auditory signals, not transient (time-varying) signals. Nearly all auditory signals of interest in vehicles have on-times long enough for the signals to be characterized as stationary auditory signals.

NOTE Sounds are generally classified as stationary for loudness calculations if their duration is longer than 0,2 s. The on-time of most signals addressed by this International Standard is longer than 0,2 s, justifying the use of DIN 45631.

4.2.3 Audibility

4.2.3.1 General

The main criterion for selecting a sound level is obtaining maximum audibility, measured against the specific ambient auditory noise within a driving vehicle. For in-vehicle auditory signals, audibility should be as high as suitable. Sound levels that are too high could lead to defensive reactions or startle reflexes inappropriate for safe driving.

4.2.3.2 Range considerations

The auditory signal should be perceivable in all ambient noise conditions for which the signal is designed (see Annex A). The upper limit should be chosen to prevent startling of the driver and hearing damage.

4.2.3.3 Minimum masked specific loudness

The auditory signal should also contain sufficient spectral content above the ambient noise in order to be audible.

For minimum audibility in a noisy environment, the signal-to-ambient ratio of specific loudness spectra at the main component of a tonal signal shall be greater than 1,3 (see A.4).

NOTE 1 The masked specific loudness spectrum includes upward spread of masking effects, where low-frequency sounds can mask the audibility of high-frequency sounds.

NOTE 2 The masked specific loudness signal-to-noise ratio (SNR) can be calculated for most tonal sounds.

4.2.4 Appropriateness

Care should be taken to avoid defensive reactions or startle reflexes caused by one or more of the following sound level characteristics: sound levels that are too high, unexpected, unknown, or are ramped to full-scale loudness too quickly.

4.2.5 Time from onset to full loudness

For critical/warning sounds, the time from onset to full loudness should be less than approximately 30 ms, so long as 4.2.4 is satisfied.

5 Coding of information

5.1 General

Information may be delivered using speech or non-speech coding, or by a combination of both according to the temporal characteristics of the auditory signal.

5.2 Temporal classification of auditory signals

5.2.1 General

The following three time categories are based on the expected time for the driver to respond to an auditory signal:

a) short-term response: 0 s – 3 s;

b) medium-term response: 3 s – 10 s;

c) longer-term response: > 10 s.

To differentiate between the time categories, different patterns of acoustical parameters (e.g. sound level, frequency) can be chosen (see 5.3).

5.2.2 Time-critical safety warnings

Time-critical auditory safety warnings always have temporal priority over non-safety-critical auditory signals, even if the non-safety signals are otherwise time-critical.

NOTE Not all auditory signals that are time-critical are also safety-critical.

5.2.3 Timing for short-term response

The auditory signal should be sent to the driver immediately after a critical event is detected by the TICS.

EXAMPLE 1 An obstacle on the vehicle pathway is detected. The driver is warned to take evasive action immediately. This is a safety warning.

EXAMPLE 2 A navigation system is providing turn-by-turn instructions, and indicates that a routed turn is imminent. This is a time-critical message, but is not a safety warning.

5.2.4 Timing for medium-term response

Auditory signals in this category may be sent immediately, if there are no other competing signals, or with a time delay of up to 10 s.

EXAMPLE Route-guidance information, e.g. “300 m ahead, left turn”.

5.2.5 Timing for longer-term response

Auditory signals in this category may be sent immediately, if there are no other competing signals of higher priority or urgency, and may be delayed so long as the driver still has sufficient time to plan and execute an appropriate response to the auditory signal.

EXAMPLE Congestion 10 km ahead.

5.3 Non-speech coding — Tonal signals

5.3.1 General

A tonal signal has two functions: attracting attention and providing information. This information is usually very specific, such as “brake immediately”. However, tonal signals may also be selected to provide information of a general nature, such as “watch out” or “danger”.

EXAMPLE 1 Announcement of a new auditory signal on a visual display (specific).

EXAMPLE 2 Rumble strips (auditory icon) to alert drivers to potential danger of unintended lane departure by causing a tactile vibration and audible rumbling.

5.3.2 Number

The number of tonal signals used in a vehicle should be limited to promote comprehensibility and distinguishability of each signal.

5.3.3 Visual redundancy

If redundant visual information is presented, both visual and tonal information should be displayed at the same time.

5.3.4 Long lasting tonal sequences

Tonal signals that are repeated either intermittently or in a continuing sequence for long periods of time (or until an appropriate action is taken by driver or occupant) should only be used in special circumstances. These circumstances include situations where the signals convey a very important message affecting the safety of the vehicle occupants or the capability to drive the vehicle.

EXAMPLE 1 A series of tones generated by a beltminder system repeat every minute to remind and encourage occupants to buckle their safety belt.

EXAMPLE 2 When the driver door is opened a continuous sequence of tones reminds the driver that the key was left in the ignition.

EXAMPLE 3 A tonal sequence is initiated at 60 km from empty fuel and is repeated every 10 km of travel distance.

5.4 Speech coding

5.4.1 General

Speech coding should only be used if the driver has sufficient time to listen to the full auditory signal before it is necessary to choose a course of action.

5.4.2 Vocabulary

5.4.2.1 Simplicity

The auditory signals or speech messages should have a simple vocabulary.

5.4.2.2 Consistency

Within each TICS application, the speech vocabulary should be consistent with the written vocabulary.

EXAMPLE The same words are used for written and spoken auditory signals.

5.4.3 Composition of auditory signal

5.4.3.1 General

A long auditory signal, especially a speech message, imposes demands on attentional resources and short-term memory. Because of these and other limitations associated with human information processing capacity, the number of information units which compose an auditory signal should be limited.

NOTE The number of information units is not necessarily the same as the number of words, for example, [close to city name] = three words, one significant unit of information.

Moreover, it takes a finite amount of time to deliver a complete auditory signal and it may not be understood until delivery is complete.

5.4.3.2 Maximum number of information units

Verbal auditory signals should consist of not more than five units of information.

If longer auditory signals have to be given, they should be separated into meaningful information units also consisting of not more than five units of information.

The more urgent the required action is, fewer words and units of information should be used.

5.4.3.3 Complex messages

In the case of complex auditory or speech information, the driver may be helped in the following ways:

— sequencing the units of information in order of potential relevance:

  1) to help the driver to quickly decide whether to “tune-in” or “tune-out”, depending on the auditory signal content

  EXAMPLE [on A 18] [close to city name] [congestion] [for 10 km];

  2) placing the action-related unit of information at the end

  EXAMPLE [on A 18] [close to city name] [congestion] [for 10 km] [take exit 7];

— providing key words (e.g. “traffic signal”), prosodic cues and highlighting;

— providing redundant visual displays, at least for the principal units of information, particularly for long-term auditory signals;

— providing a means for the driver to request that the auditory signal be repeated;

— providing a way to stop the auditory or speech information.

6 Prioritization of auditory signals

Auditory signals should be classified according to the urgency of the driver’s intended action and its safety criticality following the procedures given in ISO/TS 16951.

7 Safety warning auditory signals

7.1 Redundancy

An auditory signal concerning the safety of the driver or other people, and requiring immediate action by the driver, shall not be presented exclusively by auditory means, but shall also be presented using another sensory channel.

Other modes for presenting the information may be visual, haptic and/or kinesthetic.

Redundancy is necessary because, owing to hearing impairment or masking ambient auditory noise, some drivers will not be able to perceive the auditory signals.

7.2 Compliance

This requirement is satisfied by inspection to verify that every auditory safety warning is also presented in another sensory mode.

Annex A
(normative)

Masked specific loudness SNR procedure

A.1 Measured quantities

A.1.1 Sones and specific loudness

Sounds shall be evaluated as loudness in sones (GD) according to DIN 45631 assuming a diffuse sound field. The sound spectrum (sone level per frequency) is evaluated by the specific loudness.

The narrowband spectrum should also be calculated for the evaluation of the auditory signal and identification of its main component.

A.1.2 Sones versus decibels

The approximate dB-SPL level of common sounds is given in Table A.1 [25]. The right column contains *approximate* sone values assuming the sounds contain only 1 kHz frequency content. Actual sone values will vary depending on actual frequency content.

Table A.1 — Sample dB and sone values

Sound	dB-SPL	*Approximate* sones
Rock concert	120	~ 256
Pneumatic hammer (at 2 m)	100	~ 64
Vacuum cleaner	80	~ 16
Busy traffic	70	~ 8
Residential area at night	40	~ 1
Rustling of leaves	20	~ 0,15
Human breathing (at 3 m)	10	~ 0,02
Threshold of hearing (good ears)	0	0

A.2 Measuring equipment

Recording equipment used to measure the sound pressure should have an upper frequency limit of at least 16 kHz. The microphone should be an omni-directional microphone.

A.3 Installation

A.3.1 Test environment

The acoustical measurements are conducted either in a laboratory environment (i.e. a quiet environment) or, preferably, with sound-generating devices installed in the vehicle in the real location. Since the loudness of a sound depends on the environment in which it is heard, it is important that the comparative evaluations of different noise sources be based on measurements made in similar environments. The test should be conducted in an environment representative of the acoustic properties of the target vehicle.

A.3.2 Microphone placement

As described in ISO 5128, the noise inside the vehicle may vary considerably with location. The primary goal is to select measuring points such that the sound in the vehicle is adequately measured and characterized by how the driver perceives the sound.

One measuring point shall be the driver's position. With the advancement of binaural recording techniques, binaural heads may be used to make this measurement. The measurement position in Clause 9 of ISO 5128:1980 shall be used in the absence of other measurement positions or techniques that show improved characterizations of how drivers perceive sound in a vehicle.

A.3.3 Outside environment

The requirements of ISO 5128 shall be followed regarding the outside acoustical environment (see Clauses 6 and 7 in ISO 5128:1980).

A.4 Calculating masked specific loudness SNR

The following procedure should be used for calculating the masked specific loudness SNR.

a) Calculate the narrowband spectrum of the auditory signal to identify the frequency of interest (e.g. the main component of a tonal signal).

b) Calculate specific loudness spectrum of auditory signal during its on-time according to DIN 45631. The auditory signal is measured in the absence of ambient noise (i.e. in a non-moving vehicle).

c) Calculate specific loudness spectrum of ambient noise according to DIN 45631. The ambient noise is measured in the desired operating conditions (e.g. speed, road surface, audio system, window position, etc.).

d) Calculate signal-to-ambient ratio of specific loudness spectra at the frequency of interest.

A.4.1 Derivation of minimum masked specific loudness

The audibility threshold described in DIN 45631 is 6 dB below the specific loudness spectrum of the ambient noise, or equivalently, a factor of 0,66 times the specific loudness spectrum of the ambient noise.

Expressed in decibels, the auditory signal shall be at least 10 dB above the masked threshold of the ambient noise [3], corresponding to a signal-to-ambient ratio of 2:0 for the specific loudness spectra.

Thus, 2 * 0,66 = 1,3, gives the minimum required signal-to-ambient ratio of specific loudness spectra at the frequency of interest (see 4.2.3.3).

See Annex B for details for converting between SPL and specific loudness.

A.4.2 Sample calculation of masked specific loudness

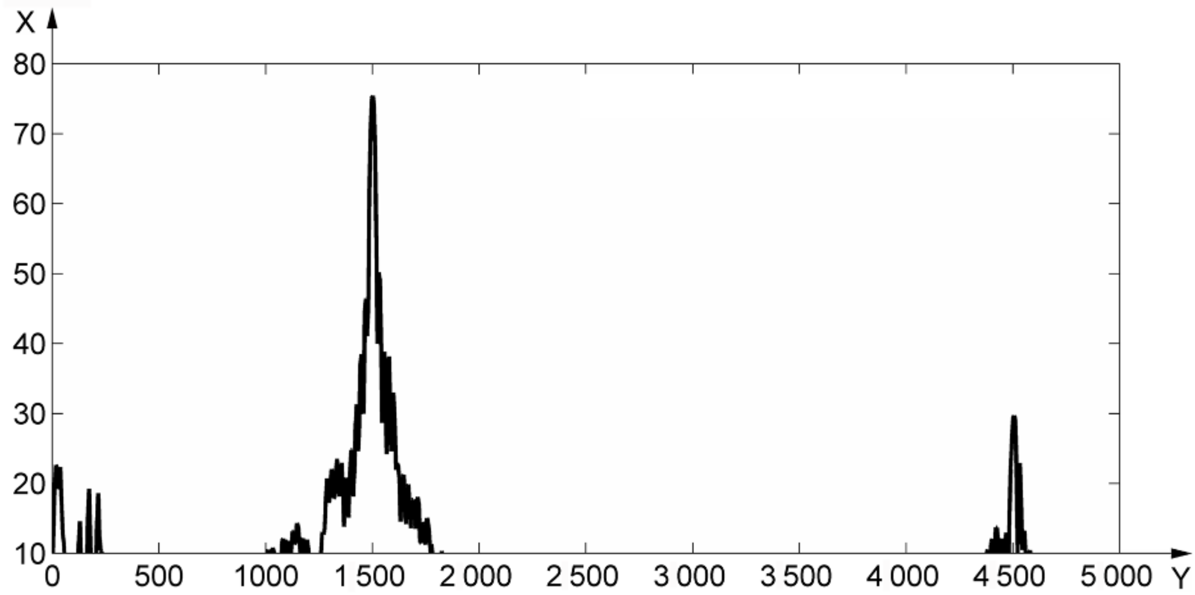
The following example is for an Integrated Vehicle-Based Safety Systems (IVBSS) Forward Collision Warning (FCW) sound.

a) To calculate signal-to-ambient ratio of specific loudness spectra at the frequency of interest, it is necessary to determine the main component of the auditory signal. The narrowband spectrum of the IVBSS [23] FCW chime is shown in Figure A.1. The main component frequency of the chime is 1 500 Hz.

b) The specific loudness spectrum for the IVBSS FCW chime ("signal") is shown in Figure A.2. The specific loudness at the frequency of interest is 6,0.

c) The specific loudness for the ambient noise (e.g. 80 mph wind noise) is shown in Figure A.3. The specific loudness at the frequency of interest is 1,2.

d) The chime-to-ambient noise ratio of the specific loudness spectra at 1 500 Hz is (6,0/1,2) = 5,0. This ratio is above the required minimum value of 1,3 (see 4.2.3.3).

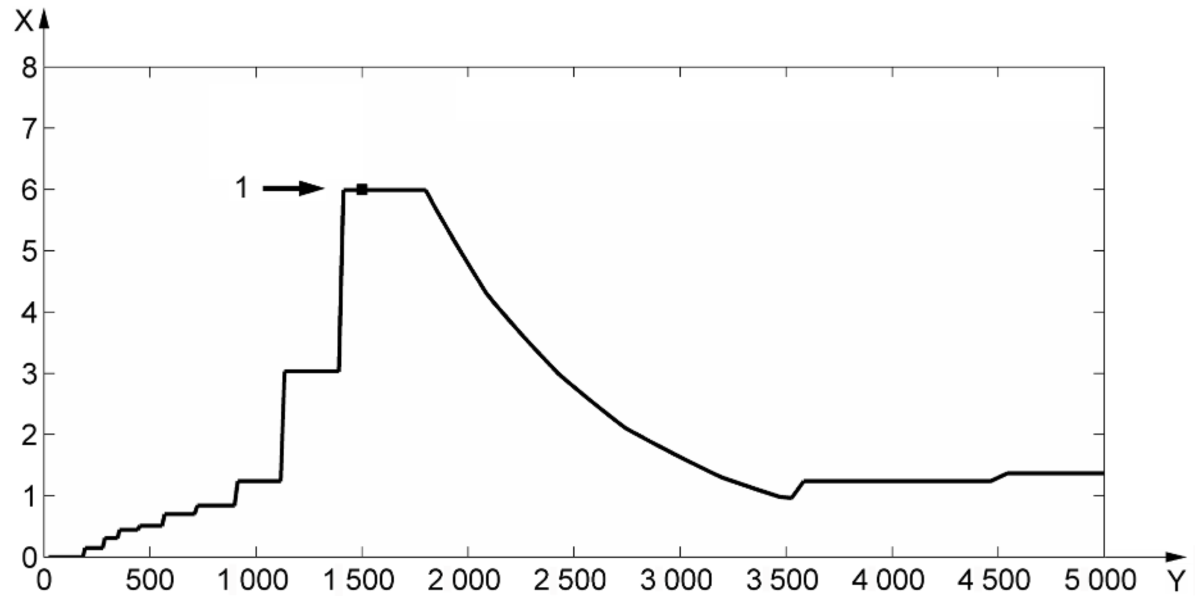


Key

X spectrum (dB-SPL)

Y frequency (Hz)

Figure A.1 — Spectrum for IVBSS FCW chime



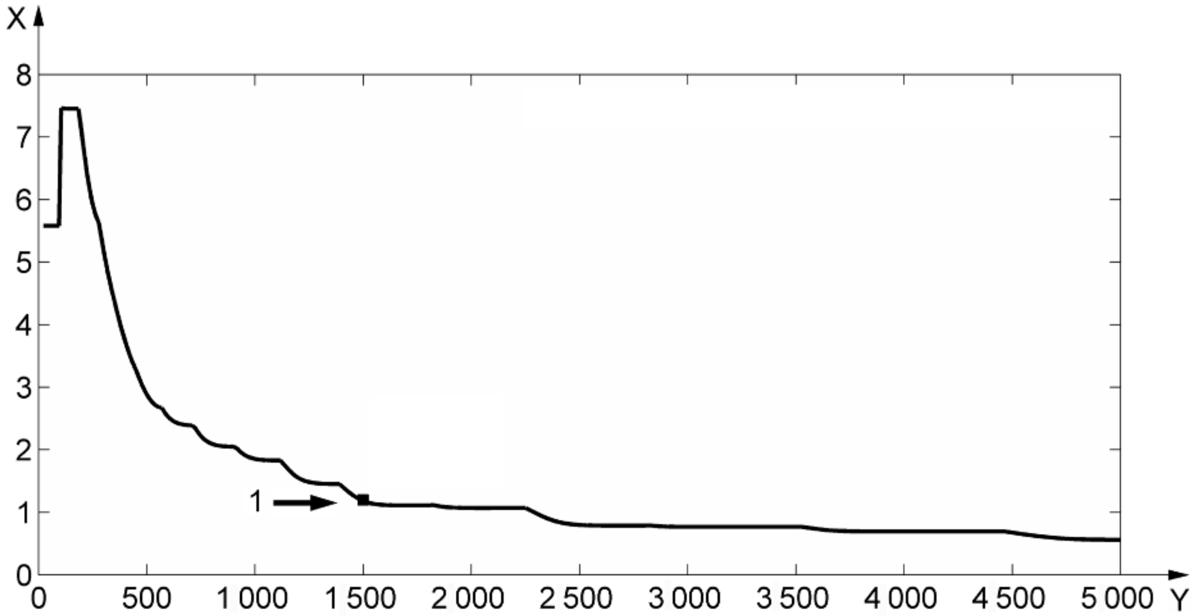
Key

X specific loudness

Y frequency (Hz)

1 specific loudness = 6 at 1 500 Hz

Figure A.2 — Masked spectrum for IVBSS FCW chime



Key

X specific loudness

Y frequency (Hz)

1 specific loudness = 1,2 at 1 500 Hz

Figure A.3 — Masked spectrum for ambient noise

Annex B
(informative)

Converting between SPL and specific loudness

For tones above 40 dB-SPL, a good approximation to the conversion between dB-SPL and sone is:

$$N = 2^{(L/10)}$$

where N is the loudness in sones and L is the loudness in dB-SPL.

Therefore, in order to calculate the audibility threshold of the ambient noise in A.4.1, reducing the ambient noise by 6 dB is well approximated by multiplying the corresponding specific loudness by $2^{(-6/10)} = 0{,}66$.

Similarly, 10 dB above the masked threshold is well approximated by multiplying the corresponding specific loudness by $2^{(10/10)} = 2$. This value is the minimum amount the signal must be above the masked threshold of the ambient noise in the specific loudness domain.

Combining the 6 dB reduction with the 10 dB increase results in an overall gain of 2 * 0,66 = 1,3. This is the minimum required signal-to-ambient ratio of specific loudness spectra at the frequency of interest.

Bibliography

[1] ISO 2575, *Road vehicles — Symbols for controls, indicators and tell-tales*

[2] ISO 7731, *Ergonomics — Danger signals for public and work areas — Auditory danger signals*

[3] ISO 9186, *Graphical symbols — Test methods for judged comprehensibility and for comprehension*

[4] ISO 9921-1, *Ergonomic assessment of speech communication — Part 1: Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method)*

[5] ISO 11429, *Ergonomics — System of auditory and visual danger and information signals*

[6] IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

[7] IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

[8] DIN 45631, *Procedure for calculating loudness level and loudness*

[9] M. WILLIAMS, E. HOESKSTRA, P. GREEN, *Development and evaluation of a Vehicle Monitor Driver Interface*, UMTRI-93-22, September 1993

[10] M.-P. BRUYAS, *Reconnaissance et compréhension de pictogrammes et symboles routiers*, Université de Lyon, 1997

[11] B. HAGERMAN, *Clinical measurement of speech reception threshold in noise, Technical audiology* ISSN 0280-6819, Report TA N107 (1983) 13

[12] O. HELLER, H.P. KRÜGER, *Recommendations for the proposal ISO/TC 22/SC 13. Auditory information presentation*, Interdisziplinäres Zentrum für Verkehrswissenschaften an der Universität Würzburg, Psychologisches Institut, 03/96

[13] H. KISHI, S. SUGIURA, *Human factors consideration for voice route guidance*, FISITA n 930553

[14] G. PACHIAUDI, M. VERNET, A. FOTI, *Noise and speech interference in light automotive vehicle*, FISITA, Dearborne, USA, 1988 n 885118

[15] R.D. PATTERSON, Auditory warning sounds in the work environment, *Phil. Trans. R.* Soc. Lond.B 328, 485-492 (1990)

[16] R.D. PATTERSON, *Guidelines for the design of auditory warning sounds*, Proc. I.O.A., Vol. 11, Part 5, pp. 17-24, 1989

[17] H. STEENEKEN, *Subjective and objective intelligibility measures, Speech processing in adverse conditions*, Proceedings of ESCA-ETRW, Cannes, 10-13 November 1992

[18] *Ergonomic criteria for in-car man machine interface*, DRIVE/ STA MMI del. 2, part 2, June 1990. DRIVE1-V1037, CEC DG 13, European Commission Host Organisation, CORDIS, Customer Service B.P. 2373, L-10243 Luxembourg

[19] K.C. PARSONS, Ergonomics of the physical environment, International ergonomic standards concerning speech communication, danger signals, lighting, vibration, and surface temperatures. *Applied ergonomics*, Vol. 26, N° 4, pp. 281-292, 1995

[20] T. ROSS, K. MIDTLAND, M. FUCHS, A. PAUZIE, A. ENGERT, B. DUNCAN, G. VAUGHAN, M. VERNET, H. PETERES, G. BURNETT, A. MAY, *HARDIE Design Guidelines Handbook, Human factors Guidelines for Information Presentation by ATT Systems*. HARDIE del.20; DRIVE II, CEC DG 13. European Commission Host Organisation, CORDIS, Customer Service B.P. 2373; L-10243 Luxembourg; March, 1996, p. 320

[21] *Calculations and application of age corrections to audiograms*. Occupational Safety and Health Standard 1910.95 App F

[22] J. Sayer, D. LeBlanc, S. Bogard, M. Hagan, H. Sandar, M. Buonarosa, and M. Barnes, *Integrated Vehicle-Based Safety Systems Field Operational Test Plan*, UMTRI-2008-51, December 2008

[23] A. Burrows, *Acoustic Noise: An Informational Definition,* Human Factors, pp. 163-169, 1960

[24] A. Pierce, *Acoustics — An Introduction to its Physical Principles and Applications*, American Institute of Physics, for the Acoustical Society of America, 1989

[25] E. Zwicker, H. Fastl, U. Widmann, K. Kurakata, S. Kuwano, and S. Namba, Program for calculating loudness according to DIN 45631 (ISO 532B), *J. Acoust. Soc. Jpn.* (E) 12, 1 (1991)

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