ITU-T

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

H.870
(03/2022)

SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

E-health multimedia systems, services and applications – Safe listening

---

Guidelines for safe listening devices/systems

Recommendation ITU-T H.870

ITU-T H-SERIES RECOMMENDATIONS

AUDIOVISUAL AND MULTIMEDIA SYSTEMS

CHARACTERISTICS OF VISUAL TELEPHONE SYSTEMS	H.100–H.199
INFRASTRUCTURE OF AUDIOVISUAL SERVICES	
General	H.200–H.219
Transmission multiplexing and synchronization	H.220–H.229
Systems aspects	H.230–H.239
Communication procedures	H.240–H.259
Coding of moving video	H.260–H.279
Related systems aspects	H.280–H.299
Systems and terminal equipment for audiovisual services	H.300–H.349
Directory services architecture for audiovisual and multimedia services	H.350–H.359
Quality of service architecture for audiovisual and multimedia services	H.360–H.369
Telepresence, immersive environments, virtual and extended reality	H.420–H.439
Supplementary services for multimedia	H.450–H.499
MOBILITY AND COLLABORATION PROCEDURES	
Overview of Mobility and Collaboration, definitions, protocols and procedures	H.500–H.509
Mobility for H-Series multimedia systems and services	H.510–H.519
Mobile multimedia collaboration applications and services	H.520–H.529
Security for mobile multimedia systems and services	H.530–H.539
Security for mobile multimedia collaboration applications and services	H.540–H.549
VEHICULAR GATEWAYS AND INTELLIGENT TRANSPORTATION SYSTEMS (ITS)	
Architecture for vehicular gateways	H.550–H.559
Vehicular gateway interfaces	H.560–H.569
BROADBAND, TRIPLE-PLAY AND ADVANCED MULTIMEDIA SERVICES	
Broadband multimedia services over VDSL	H.610–H.619
Advanced multimedia services and applications	H.620–H.629
Content delivery and ubiquitous sensor network applications	H.640–H.649
IPTV MULTIMEDIA SERVICES AND APPLICATIONS FOR IPTV	
General aspects	H.700–H.719
IPTV terminal devices	H.720–H.729
IPTV middleware	H.730–H.739
IPTV application event handling	H.740–H.749
IPTV metadata	H.750–H.759
IPTV multimedia application frameworks	H.760–H.769
IPTV service discovery up to consumption	H.770–H.779
Digital Signage	H.780–H.789
E-HEALTH MULTIMEDIA SYSTEMS, SERVICES AND APPLICATIONS	
Personal health systems	H.810–H.819
Interoperability compliance testing of personal health systems (HRN, PAN, LAN, TAN and WAN)	H.820–H.859
Multimedia e-health data exchange services	H.860–H.869
Safe listening	**H.870–H.879**

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T H.870

Guidelines for safe listening devices/systems

Summary

Recommendation ITU-T H.870 describes the requirements on safe listening devices and systems, called personal/portable audio systems, especially those for playing music, to protect people from hearing loss. It also gives a glossary for common understanding as well as background information on sound, hearing and hearing loss.

It recommends the criteria for avoiding unsafe listening: one for adults and the other for children, both based on the equal energy principle, the assumption that equal amounts of sound energy will cause equal amounts of sound induced permanent threshold shift regardless of the distribution of the energy over time.

Importantly, this Recommendation provides guidelines on health communication for safe listening so that appropriate warning messages can be delivered effectively when necessary. Examples of such messages can be found in Appendix VII.

Finally, this Recommendation also gives information about the implementation of dosimetry and related issues.

Communication devices and assistive devices are excluded from the scope of this Recommendation. Gaming devices are also for future study.

This standard was developed collaboratively by the World Health Organization (WHO) and ITU under the 'Make Listening Safe' initiative, and it is adopted by both organizations.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T H.870	2018-08-29	16	11.1002/1000/13686
2.0	ITU-T H.870 (V2)	2022-03-16	16	11.1002/1000/14953

Keywords

Dose, personal audio system, safe listening, sound pressure level, sound-induced hearing loss.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Introduction

There is growing concern about the rising exposure to loud sounds in recreational settings such as nightclubs, discotheques, pubs, bars, cinemas, concerts, sporting events and even fitness classes. With the popularization of technology, devices such as personal audio systems are often listened to at high volumes and for prolonged periods of time. Regular participation in such activities poses a serious threat of irreversible hearing loss.

The World Health Organization (WHO) estimates that [b-WHO-2018]:

– Over 1.5 billion people globally experience some degree of hearing loss due to different causes. Of these, 430 million require hearing rehabilitation to ensure optimal functioning. These numbers are projected to rise in coming decades, unless action is taken to mitigate risk factors for hearing loss.

– Over a billion young people worldwide could be at risk of hearing loss due to unsafe listening practices.

– Among teenagers and young adults 12 to 35 years old in middle- and high-income countries:
  - Nearly 50% listen to unsafe levels of sound with the use of personal audio devices such as MP3 players and smartphones.
  - Around 40% are exposed to potentially damaging sound levels at nightclubs, discotheques and bars.

The increasing sales of smartphones, with over 1.5 billion devices sold globally in 2019 alone, is another indicator of potential risk. This increased accessibility and use of personal audio systems for listening to music is coupled with their use at high volume and for long durations. Such risk-associated behaviours can permanently damage hearing capacity.

In consideration of these facts, WHO launched the 'Make Listening Safe' initiative in 2015. The overall vision of this initiative is to ensure that people of all ages can enjoy listening with full protection of their hearing.

Its aim is to reduce the risk of hearing loss posed by unsafe exposure to sounds in recreational settings. In order to achieve this, WHO has identified three specific objectives:

1) Regulate exposure to loud sounds through personal audio systems.
2) Change listening behaviours among the target population.
3) Limit sound exposure in recreational settings.

This Recommendation is a result of the collaboration between WHO and ITU on the 'Make Listening Safe' initiative, and is a common standard recognized by both organizations.

Recommendation ITU-T H.870

Guidelines for safe listening devices/systems

1 Scope

This Recommendation describes the requirements on safe listening devices and systems, especially those for playing and listening to music, to protect people from hearing loss.

As market trends have blurred the distinction between some listening devices and personal audio devices, use-cases are included to ensure this Recommendation applies as widely as reasonably practicable.

NOTE 1 – Some of these use-cases follow the principle of classifying energy sources and prescribing safeguards against those sources as enshrined in [IEC 62368-1].

For the purposes of this Recommendation, the following types of devices are excluded:

– two-way communication devices (such as walkie-talkies, etc.);

– rehabilitative and medical devices (e.g., hearing aids, FM systems and other assistive listening devices (ALD) approved as part of hearing aid and cochlear implant systems, etc.);

– personal sound amplification products/devices;

– professional audio equipment and devices.

NOTE 2 – There are concerns about the exposure to sound from portable game consoles, but this is for future study.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.100.1] Recommendation ITU-T G.100.1 (2015), *The use of the decibel and of relative levels in speechband telecommunications*.

[ITU-T P.57] Recommendation ITU-T P.57 (2021), *Artificial ears*.

[ITU-T P.58] Recommendation ITU-T P.58 (2021), *Head and torso simulator for telephonometry*.

[ITU-T P.380] Recommendation ITU-T P.380 (2003), *Electro-acoustic measurements on headsets.*

[ITU-T P.381] Recommendation ITU-T P.381 (2020), *Technical requirements and test methods for the universal wired headset or headphone interface of digital mobile terminals*.

[ITU-T P.382] Recommendation ITU-T P.382 (2020), *Technical requirements and test methods for multi-microphone wired headset or headphone interfaces of digital wireless terminals*.

[EN 50332-1] CENELEC EN 50332-1:2013, *Sound system equipment: Headphones and earphones associated with personal music players. Maximum sound pressure level measurement methodology. General method for "one package equipment".*

[EN 50332-2] CENELEC EN 50332-2:2013, *Sound system equipment: Headphones and earphones associated with personal music players. Maximum sound pressure level measurement methodology. Matching of sets with headphones if either or both are offered separately, or are offered as one package equipment but with standardised connectors between the two allowing to combine components of different manufacturers or different design*.

[EN 50332-3] CENELEC EN 50332-3:2017, *Sound system equipment: Headphones and earphones associated with personal music players – Maximum sound pressure level measurement methodology – Part 3: Measurement method for sound dose management*.

[IEC 60268-1] IEC 60268-1:1985, *Sound system equipment – Part1: General*.

[IEC 61252] IEC 61252:1993, *Electroacoustics – Specifications for personal sound exposure meters*, including its AMD1:200 and AMD2:2017.

[IEC 61672-1] IEC 61672-1:2013, *Electroacoustics – Sound level meters – Part 1: Specifications.*

[IEC 62368-1] IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*.

[ISO 226] ISO 226:2003, *Acoustics – Normal equal-loudness-level contours*.

[ISO 11904-1] ISO 11904-1:2002, *Acoustics – Determination of sound immission from sound sources placed close to the ear – Part 1: Technique using a microphone in a real ear (MIRE technique).*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 calculated sound dose [IEC 62368-1]: One-week rolling estimate of sound exposure expressed in percent of the maximum regarded as safe.

NOTE – See B.4 of [EN 50332-3] for additional information.

3.1.2 diffuse-field frequency response of HATS (sound pick-up) [ITU-T P.58]: Difference, in dB, between the third-octave spectrum level of the acoustic pressure at the ear-drum reference point (DRP) and the third-octave spectrum level of the acoustic pressure at the HATS reference point (HRP) in a diffuse sound field with the HATS absent.

3.1.3 eardrum reference point [b-ITU-T P.10]: A point located at the end of the ear canal, corresponding to the eardrum position.

3.1.4 free sound field [ISO 3745]: A field in a homogenous, isotropic medium free of boundaries.

3.1.5 free-field frequency response of HATS (sound pick-up) [ITU-T P.58]: Difference, in dB, between the third-octave spectrum level of the acoustic pressure at the ear-drum reference point (DRP) and the third-octave spectrum level of the acoustic pressure at the HATS reference point (HRP) in a free sound field with the HATS absent (test point).

3.1.6 head and torso simulator (HATS) [b-ITU-T P.10]: Manikin extending downward from the top of the head to the waist, designed to simulate the sound pick-up characteristics and the acoustic diffraction produced by a median human adult and to reproduce the acoustic field generated by the human mouth.

3.1.7 instructed person [IEC 62368-1]: Instructed person is a term applied to persons who have been instructed and trained by a skilled person, or who are supervised by a skilled person, to identify energy sources that may cause pain (see Table 1) and to take precautions to avoid unintentional contact with or exposure to those energy sources. Under normal operating conditions, abnormal operating conditions or single fault conditions, instructed persons should not be exposed to parts comprising energy sources capable of causing injury.

3.1.8 material hearing impairment [b-NIOSH]: An average of the hearing threshold levels for both ears that exceeds 25 dBHL at 1000, 2000, 3000 and 4000 Hz.

3.1.9 microphone-in-real-ear [ISO 11904-1]: Refers to measurements carried out using miniature or probe microphones inserted in the ears of human subjects.

3.1.10 momentary exposure level [IEC 62368-1]: Metric for estimating 1*s* sound exposure level from the HD 483-1 S2 test signal applied to both channels, based on [EN 50332-1], clause 4.2.

NOTE 1 – MEL is measured in dB.

NOTE 2 – See B.3 of [EN 50332-3] for additional information.

3.1.11 ordinary person [IEC 62368-1]: Ordinary person is the term applied to all persons other than instructed persons and skilled persons. Ordinary persons include not only users of the equipment, but also all persons who may have access to the equipment or who may be in the vicinity of the equipment. Under normal operating conditions or abnormal operating conditions, ordinary persons should not be exposed to parts comprising energy sources capable of causing pain or injury. Under a single fault condition, ordinary persons should not be exposed to parts comprising energy sources capable of causing injury.

3.1.12 personal music/media player [IEC 62368-1]: A personal music player is a portable equipment intended for use by an ordinary person, that:

– Is designed to allow the user to listen to audio or audio-visual content / material; and

– Uses a listening device, such as headphones or earphones that can be worn in or on or around the ears; and

– Has a player that can be body worn (of a size suitable to be carried in a clothing pocket) and is intended for the user to walk around while in continuous use (for example, on a street, in a subway, at an airport, etc.).

NOTE – Examples are portable CD players, MP3 audio players, mobile phones with MP3 type features, PDAs or similar equipment.

3.1.13 skilled person [IEC 62368-1]: Skilled person is a term applied to persons who have training or experience in the equipment technology, particularly in knowing the various energies and energy magnitudes used in the equipment. Skilled persons are expected to use their training and experience to recognize energy sources capable of causing pain or injury and to take action for protection from injury from those energies. Skilled persons should also be protected against unintentional contact or exposure to energy sources capable of causing injury.

3.1.14 sound exposure [EN 50332-3]: A-weighted sound pressure, p_A, squared and integrated over a stated period of time between $t2$ and $t1$:

$$E = \int_{t1}^{t2} (p_A(t))^2 dt$$

3.1.15 sound pressure level [b-ITU-R V.574]: The logarithm, generally expressed in decibels (dB SPL), of the ratio of sound pressure and a reference pressure p_0, often 20 μPa. Note that a factor of 20 is used when the ratio is between two sound pressures, rather than between two sound intensities.

$$SPL = 20log10\left(\frac{p}{p_0}\right)$$

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 acoustic reflex threshold: The sound pressure level (SPL) at which a sound stimulus triggers stapedius muscle reflex (SMR).

3.2.2 acoustic trauma: A single exposure to sound resulting in immediate injury to the auditory system.

3.2.3 damage-risk criteria: An archaic term referring to the risk of noise induced hearing loss (NIHL) presented by various levels of noise exposure. In this Recommendation this term is replaced with several preferred contemporary terms: 'dose-response relationship', 'risk', or 'exposure limit'.

3.2.4 dBA: Decibels of sound pressure level measured using the A-weighting network [IEC 61672] and]IEC 60268-1], see also Figure II.2; a frequency weighting intended to measure low-intensity noise (around 40 phon loudness level) but which has also become commonly used for measuring occupational and environmental noise exposures.

NOTE – The latter use is based on studies of noise-exposed workplace populations in the 1950s and 1960s. That work recommended the use of A-weighting given both its availability in sound level meters and its ability to predict the dose-response relationship over the noise spectra studied [b-Burns-1973] and [b-Burns-Robinson]. Subsequent to that work, the analyses of noise exposed populations upon which the weekly sound allowance in this document are based used A-weighting in measuring noise exposure [b-Neitzel] and [b-Fligor].

3.2.5 dBFS: dB full scale is the signal level of a digital signal relative to its overload or maximum level. Different conventions exist. It is common to assign a digital representation of a full-scale sinusoidal the value of 0 dBFS RMS. The peak level can then reach +3.01 dBFS. In other cases, the RMS level of a digital full-scale square wave is assigned 0 dBFS RMS. The maximum peak level is then also 0 dBFS. For the latter cases, dBFS is equivalent to dBov. (dBov: dB relative to digital overload is the signal level of a digital signal relative to its overload or maximum level. See [ITU-T G.100.1].)

3.2.6 dBHL: Decibels of hearing level at a certain frequency; a level used to measure an audiometric hearing threshold relative to the level defined as normal.

NOTE – It is the ear's sensitivity in a human with normal hearing, at different frequencies, that is the reference. Figure 1 of [ISO 226] shows standardized equal-loudness contours at different sound levels and a mapping of phon (loudness) against dB SPL (level). The two scales meet at 1 kHz. dB SPL is by definition referenced at the threshold of hearing at 1 kHz, i.e., 0 phon (and 0 dB SPL).

3.2.7 diffuse sound field: A field where at any position in the medium, sound is incident from all directions with equal intensities and random phase. The reverberant sound does not vary with receiver position. (Adapted from [b-Vér].)

3.2.8 (sound) dose: The total quantity of sound energy received by the human ear during a specified period. In the context of this Recommendation, it is the same as sound exposure (see clause 3.1.14). The unit of (sound) dose is Pa^2h.

3.2.9 dosimetry: The calculation and assessment of the dose received by the human ear.

3.2.10 equal energy principle: The premise that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time. According to this principle, equal amounts of sound energy are expected to cause equal amounts of sound induced permanent threshold shift regardless of the distribution of the energy across time. This principle allows the question of hearing damage risk posed by a sound exposure to be related to a sound dose.

3.2.11 equivalent continuous A-weighted sound pressure level: A continuous sound pressure level (SPL) in dBA which is considered to pose the same risk as a time-varying SPL, calculated using a 3-dB exchange rate between level and time. Mathematically, it is represented as:

$$L_{Aeq,T} = 10\lg\left\{\left[\frac{1}{T}\int_{t_1}^{t_2} p_A{}^2(\mathrm{t})\mathrm{d}t\right]/p_0^2\right\}\ dBA$$

where:

$L_{\mathrm{Aeq},T}$ is the equivalent continuous A-weighted sound pressure level re 20 μPa, determined over a time integration interval $T = t_2 - t_1$

$p_A(t)$ is the instantaneous A-weighted sound pressure of the sound signal

p_0 is the reference sound pressure of 20 μPa.

3.2.12 equivalent continuous average sound level normalized: A continuous SPL in dBA which is considered to pose the same risk as a certain time-varying SPL pattern measured using a 3-dB exchange rate and normalized to an *n*-hour exposure period. For example, the value for *n* could be 8, in which case this may also be referred to as an L_{A8hn} or L_{EX8h}", or *n*=40, L_{EX40h}.

3.2.13 excess risk: The risk of sound induced hearing loss (SIHL) associated with a specific amount of exposure.

3.2.14 exchange rate: The change in average noise level (in dB) that corresponds to a doubling or halving of allowable exposure time.

3.2.15 frequency response: In this context, frequency response is short for "sensitivity vs. frequency response", sometimes referred to as the "tone curve" of an audio device, such as a headphone, loudspeaker, microphone, amplifier, etc.

3.2.16 hearing threshold level: Sound pressure level (SPL) at specific audiometric test frequencies, measured in dBHL.

3.2.17 listening device: A wearable device used to deliver sound to the ear.

Consists of a transducer and fitting to accommodate in the ear, on the ear or over the ear listening. Examples are headphones and earphones.

Headphones and earphones may include amplifiers and other electronics, such as for wireless or digital connection, signal processing, noise cancellation, or even media storage for subsequent playback. As such, headphones and earphones with such functionality could be classed as personal audio systems.

NOTE – The principle of classifying energy sources and proscribing safeguards against those sources is enshrined in [IEC 62368-1], on which much of this Recommendation is based.

3.2.18 media: Audio or audio-visual content for the purposes of entertainment whereby long-term exposure may result in hearing loss. Examples are music, gaming and podcasts.

3.2.19 personal audio device: A portable device designed to be worn on the body or fit in the clothing pocket to listen to various forms of media. It can be connected to a listening device. An example of a personal audio device is a personal media player (PMP).

3.2.20 personal audio system (PAS): A system of a personal audio device and a listening device. Examples are a personal media player (PMP) connected to headphones, and headphones capable of playing locally stored content independently of an external PAD.

3.2.21 safe listening device: A personal audio device/system that meets the requirements and criteria to minimize the users' risk of acquiring hearing loss, (as a consequence of its use) can possibly be termed as a safe listening device. It could include music players (MP3 players, smartphones and personal music players) used with a listening device.

3.2.22 sound allowance: A dose estimate of sound exposure over a certain rolling period of time (e.g., daily or weekly), commonly expressed as a percentage of the maximum regarded as safe. A weekly sound allowance is equivalent to 100% calculated sound dose (CSD).

3.2.23 sound-induced: Refers to a state or a quality resulting from exposure to sound. The sound may be (part of) music or "noise", which implies the sound is not desirable.

3.2.24 sound-induced permanent threshold shift: Synonymous with permanent sound induced hearing loss (SIHL).

3.2.25 sound-induced temporary threshold shift: Sound induced hearing loss (SIHL) that results from exposure to sound but recovers after a sufficient time spent in low sound conditions.

3.2.26 sound-induced tinnitus: Perception of phantom sound in the ears or head that are either temporary or permanent, following excessive sound exposure.

3.2.27 stapedius muscle reflex: The process in which the stapedius and tensor tympani muscles of the ossicles contract when the ear is exposed to high intensity sound. This is also called auditory reflex.

3.2.28 transducer: An electronic device that converts energy from one form to another.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ALD Assistive Listening Devices

ANR Active Noise Reduction

ART Acoustic Reflex Threshold

CLL Chosen Listening Level

CSD Calculated Sound Dose

DAC Digital to Analogue Conversion

dBA Decibels of sound pressure level measured using the A-weighting network

dBFS Decibel Full Scale

dBHL Decibels of Hearing Level

DRP Eardrum Reference Point

ER Exchange Rate

HATS Head And Torso Simulator

HTL Hearing Threshold Level

LEQ Equivalent continuous average sound level

LEX Equivalent continuous average sound level normalized

MIRE Microphone-In-Real-Ear

NIHL	Noise Induced Hearing Loss
NIPTS	Noise Induced Permanent Threshold Shift
PAD	Personal Audio Device
PAS	Personal Audio System
PLD	Personal Listening Device
PMP	Personal Media Player
RMS	Root Mean Squared
SEL	Sound Exposure Level
SIHL	Sound Induced Hearing Loss
SLD	Safe Listening Device
SMR	Stapedius Muscle Reflex
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
VR	Virtual Reality

5 Conventions

None.

6 Safe listening: Introduction

Temporary and permanent hearing threshold shifts from exposure to sound and noise is an increasing public health problem, particularly in children and adolescents. In fact, sound-induced hearing loss (SIHL) is the leading cause of preventable hearing loss in the world. From the early 1990s to 2000, it was estimated that the number of young people with SIHL has increased from 6.7% to 18.8%. Some of this can be attributed to the fact that in this day and age, young people are utilizing their leisure time with activities that expose them to high levels of music using personal audio systems (PAS) or attending communal events such as concerts, bars, clubs, etc. Despite this emerging epidemic, there are currently almost no standards set to limit sound exposure in non-occupational settings, especially for PAS. This Recommendation addresses this standardization gap.

It may be considered that prevention of hearing loss through safe listening practices is the responsibility of the individual. However, the onus of raising awareness and creating an environment for safe listening lies with the community, manufacturers of devices, governments and other stakeholders.

Hearing loss can occur as a consequence of listening to high levels of sound over prolonged periods of time. The unsafe use of personal audio devices (PADs) poses a threat to the hearing of millions.

Such hearing loss is permanent, but it can largely be prevented through safe listening practices. Appropriate technology can help to reduce the risk of unsafe listening. A personal audio device/system in compliance with standards which serve to minimize the users' risk of acquiring hearing loss, (as a consequence of its use) can possibly be termed as a safe listening device/system.

The term safe listening refers to listening behaviour that does not put peoples' hearing at risk. A person's risk of losing his/her hearing depends on how loud, for how long and how often the person is exposed to loud sounds. Such exposure may be through personal audio devices or in entertainment venues as well as in the surrounding environment, such as in traffic, in the workplace or at home.

The term sound allowance refers to the acceptable level of sound energy an individual can receive without putting his/her hearing at risk. The term "weekly sound allowance" is equivalent in meaning to "100% calculated sound dose (CSD)" (see clause 3.1.1). It is recommended to use the term 'sound allowance' for health communication purposes, rather than 'dose'. It should be also noted that the sound allowance determined as described by this Recommendation ignores sound exposure from sources other than personal audio devices. Depending on what those exposures are, a risk of hearing loss may still exist for an individual.

Use-cases for consideration when applying this Recommendation can be found in [b-FSTP-SLD-UC].

6.1 Background

Appendix VIII provides background information for safe listening.

6.2 Personal audio system

The definition for personal audio system (PAS) is given in clause 3.2.20, and Figure 6-1 shows the general architecture of a PAS.

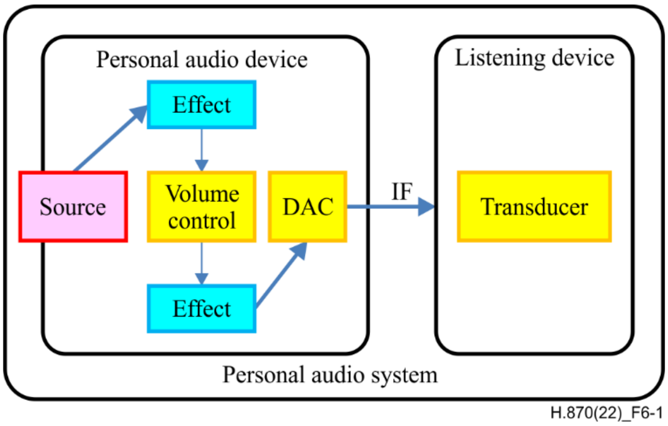


Figure 6-1 – Architecture of a personal audio system (PAS)

In this diagram, "source" can be either stored locally on the device or retrieved remotely, e.g., streamed from a local server or the Internet.

A PAS is intended for use by an ordinary person and

– is designed to allow the user to listen to audio or audio-visual content/material; and

– uses a listening device, such as headphones or earphones that can be worn in or on or around the ears; and

– has a player that can be body worn (of a size suitable to be carried in a clothing pocket) and is intended for the user to walk around with while in continuous use (for example, on a street, in a subway, at an airport, etc.); and

– has means the user uses to adjust the volume of sound delivered to the ear.

Examples are portable CD players; MP3 audio players; mobile phones or tablets smart watches with MP3 type features; headphones which can locally store audio content or with built-in wireless connection to a music server without use of a separate PAD.

The requirements do not apply to:

– professional equipment;

– hearing aid equipment and other devices for assistive listening;

– the following type of analogue personal music players:

  - o long distance radio receiver (for example, a multiband radio receiver or world band radio receiver, an AM radio receiver), and
  - o cassette player/recorder;

NOTE 1 – This exemption has been allowed because this technology is falling out of use, and it is expected that in a few years it will no longer exist. This exemption will not be extended to other technologies.

– a player while connected to an external amplifier that does not allow the user to walk around while it is in use.

NOTE 2 – In addition to the above, communication devices are excluded from the scope of this Recommendation.

NOTE 3 – In the meantime, the immediate focus is on music, but gaming and virtual reality is for future study.

6.2.1 Consideration of headphones and earphones

The situation of headphones/earphones listening using portable equipment is different from domestic loudspeaker reproduction. Studies of the habits of headphone listening with portable music players indicate that the listening level varies greatly from person to person [b-SCENIHR]. With some portable players and headphones it is possible to play at high levels. The portability of the equipment also increases the risk of reaching high exposure times.

When exposed to a high-level sound field such as in a concert or club, there may be perceivable body vibration in addition to stimuli via the ears. In the case of earphones/headphones, the vibration part is missing.

Figure 6-2 contains an example of the relationship between headphone type (earbuds and supra-aural or isolators) and chosen listening levels (CLLs) depending on the surroundings (airplane, bus, quiet, etc.).

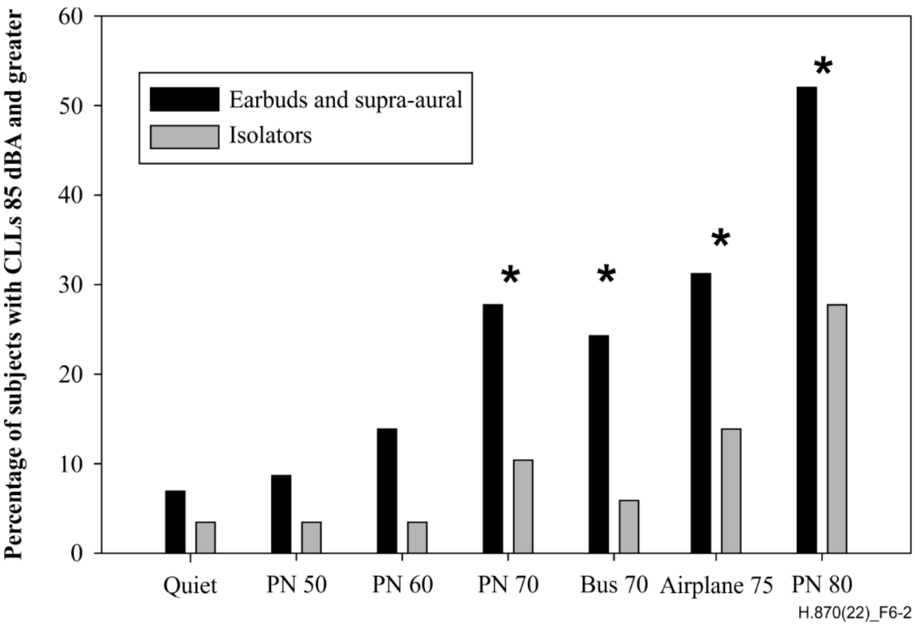


Figure 6-2 – Headphone type and chosen listening level [b-Portnuff]

6.2.2 Note on individuality

Individual differences in the dimensions of the ear canal affect the frequency and amplitude of the ear canal resonance.

That consideration of factors such as height and gender differences as well as the head circumference of an individual or even the measurement of the resonance characteristics of the ear canal of an individual will lead to alleviating the individual differences is strongly suggested by the hitherto medical practices.

6.2.3 Guidance on measurement

If measuring the analogue electrical output level of a PAS, the procedures described in clause 7.2.2 of [ITU-T P.381] using the relevant specified test set-up, should be used. This includes playback of a certain programme simulation signal at a defined digital level, simulation of the headphones using a resistive load and appropriate measurement of the output voltage of the player.

If measuring the overall electro-acoustic sensitivity of headphones/earphones, the procedures described in clause 8.2.2 of [ITU-T P.381] using the relevant specified test set-up, should be used. If measuring the electro-acoustic sensitivity of headphones/earphones as a function of frequency, the procedures described in clause 8.1.5 of [ITU-T P.381] using the relevant specified test set-up, should be used. This may be used for example for a dose estimator, as described in Appendix II of this Recommendation.

These headphone measurements include playback of a certain programme simulation signal at a defined electrical level, a head and torso simulator (HATS), appropriate measurement of the output sound pressure for a certain input voltage, including averaging over several 're-seatings' of the headphones on the HATS.

These ITU-T Recommendations partly refer to the CENELEC EN 50332 series of specifications, for harmonization purposes. For digital interfaces, guidance is also found in the CENELEC specifications.

NOTE – [ITU-T P.381] refers to the commonly used 3-pole or 4-pole 3.5 mm or 2.5 mm diameter jack/plug. For 5-pole connectors, guidance is found in [ITU-T P.382].

If measuring the overall acoustic output level of a portable music player including headphones/earphones, the procedure in [EN 50332-1] should be used.

7 Damage risk criteria

7.1 Operational modes

It is required that PASs or PADs shall include a system that tracks the user's exposure time, and estimates sound level and usage of a reference exposure (sound allowance). This includes all media playback through the device or system (i.e., stored locally or streamed) during times when the user is using ear/headphones. Voice calls may be excluded as they are specified separately by other standards.

This system shall determine the exposure of the user based on the following mode:

– Mode 1: (WHO) standard level for adults: this will apply 1.6 Pa^2h per 7 days as the reference exposure.

  NOTE 1 – The value is adapted from [IEC 62368-1] and is based on the values mentioned in [b-2009/490/EC], which stipulated that sound is safe when below 80 dB(A) for a maximum of 40 hours per week. Therefore, the value of 100% calculated sound dose (CSD) corresponds to 80 dB(A) for 40 hours.

It is recommended that the device or system offer a more conservative mode to users that prefer or benefit from a more conservative level as outlined in mode 2:

– Mode 2: (WHO) standard level for users that prefer or may benefit from lower sound levels (e.g., for children): this will apply 0.51 Pa^2h per 7 days as the reference exposure.

The device or system should allow the users to select their reference exposure as one of the above-mentioned two modes.

NOTE 2 – Reference exposures are derived from 80 dBA (Mode1) and 75 dBA (Mode 2) SPL for 40 hours per week (which in turn is derived from 8 hours per day, 5 days/week).

NOTE 3 – An alternative to expressing exposure in terms of % used, is to express the *time left* until reaching a certain exposure (e.g., remaining playback time at the current playback level until reaching 100%).

It is recommended that mode choice be given when using the player for the first time (or when the device is reset to factory settings). It is recommended that the user be able to change the mode choice at any later time, e.g., via a device configuration menu.

Examples of weekly listening time duration based on sound allowance for the modes above can be found in Table 1 and Table 2.

Table 1 – Example of weekly listening time for Mode 1

dB(A) SPL	Weekly (1.6 Pa^2h)
107	4.5 min
104	9.5 min
101	19 min
98	37.5 min
95	75 min
92	2.5 h
89	5 h
86	10 h
83	20 h
80	40 h

Table 2 – Example of weekly listening time for Mode 2

dB(A) SPL	Weekly (0.51 Pa^2h)
107	1.5 min
104	3 min
101	6 min
98	12 min
95	24 min
92	48 min
89	1 h 36 min
86	3 h 15 min
83	6 h 24 min
80	12 h 30 min
77	25 h
75	40 h

7.2 Uncertainty in dose estimate

In estimating sound dose there is some uncertainty. Some sources for uncertainties are:

– sound source;
– variation in headphone characteristics of a single model, due to production tolerances;
– variation due to unknown headphone type;
– manufacturing tolerance;
– errors due to incorrect manual selection of headphone type;
– variations in fit to the artificial ear during characterization;
– imperfect relation between artificial ears and real ears;
– imperfect relation between a standardized diffuse-field correction and a variety of human head-related transfer functions;
– variations in fit to the human ears;
– uncertainties in characterization of player characteristics, especially due to non-linear processing in the alternative implementation shown in Figure II.5;
– errors in calculations;
– users' individual susceptibility to sound exposure;
– exposure from other sources.

Since some of these uncertainties are typically several dB, and an error of 3 dB constitutes a 100% dose error, uncertainties of dose estimation can be expected to be hundreds of percent. It is therefore suggested to refrain from signalling "safe" and "green" to the user based on dose readings below a certain limit.

The dose estimation is however relevant in accounting for the general trends:

– higher signal level means higher risk
– longer exposure means higher risk
– the spectral content of the music is accounted for.

Further details on this subject remain for future study.

8 Measurement methods

8.1 Dosimetry

8.1.1 Main related standards

[EN 50332-1], [EN 50332-2] and [EN 50332-3] describe a dose measurement system in a PMP. [IEC 61252] describes acoustic dosimeters to be worn on the body.

8.1.2 Definition of dose in the context of acoustic dosimetry

A dose in the context of acoustic dosimetry is calculated as follows:

$$dose = \int_{t1}^{t2} (p_A(t))^2 dt$$

where p_A is the A-weighted and diffuse-field corrected sound pressure.

For example, the dose acquired when being subjected to 80 dBSPL(A) during an exposure duration of 40 h is calculated as follows:

– The root mean square (RMS) sound pressure is $10^{\frac{80}{20}} \cdot \frac{20\mu Pa}{1Pa} = 0.2\ Pa$. Consequently, the dose is $0.2^2 \cdot 40 = 1.6\ Pa^2h$.

Such a specific dose may be defined as a reference dose and the measured exposure estimation during a certain period may be expressed as a percentage of this reference dose.

1.6 Pa^2h constitutes 100% weekly sound allowance, corresponding to 100% calculated sound dose (CSD) as defined in [EN 50332-3].

For an example of dosimetry implementation, see Appendix II.

8.1.3 Testing of dosimeter functionality

The dosimeter functionality is tested by playing the programme simulation sound according to [EN 50332-1] and [IEC 60268-1] and measuring the time until the dose estimate reaches 100% CSD, using interpolation and tolerances as described in [EN 50332-3]. Such testing may be performed in the acoustic domain (when a headset of known sensitivity versus frequency response is used) or in the electrical domain using a 32 Ω resistive load (when the headset characteristics are unknown). See measurement set-up information in [ITU-T P.381].

NOTE – Testing methods for digital signal such as in [EN 50332-1] should also be considered and are for further study.

It is recommended to verify that the dose grows at twice the rate for every 3 dB increase in output level when varying content levels from −28 to −4 dBFS (see dBFS definition in [EN 50332-1]) and similarly when varying volume control settings.

It is recommended to test the A-weighting filter and other detailed dosimeter characteristics as described in [IEC 61252].

9 Sensitivity range and frequency response of headphones

Knowledge of the gain of the signal chain from volume control(s) available to the user and the sensitivity of the listening device are important for calculating the sound dose with reasonable precision. For the simplest PAS comprised of a PAD connected to a passive headphone (containing no electronics) of an unknown type, the calculated sound dose shall assume the maximum permitted headphone sensitivity [EN 50332-3].

However, the user convenience resulting from headphones with digital wireless or wired interfaces has led to a rapid shift away from such simple passive headphones. This brings new possibilities to make CSD more accurate and foster safe listening better, including:

– Communication of sensitivity, including changes due to internal processing, by a listening device to a PAD.
– Calculation within the listening device of CSD increments during a listening session, for communication to PADs.
– System knowledge of the quality of the seal to the individual user's ears, providing a more relevant sensitivity value than that measured on laboratory acoustic test mannequins.
– Personalised processing to improve clarity of content, making lower levels more acceptable.

An increasingly common PAS that is capable of implementing these possibilities is comprised of a smartphone PAD connected via Bluetooth to a headphone containing signal processing capabilities. Given these existing technical capabilities and to spur future developments, two general principles are recommended:

– Calculation of sound dose increments should be determined as late as possible in the signal chain – from stored music file to the ear, as this is where the best estimate of increments to CSD are to be had. In particular, CSD increments shall include the effect of all volume controls in the signal chain.

– Accumulating the CSD over time to determine the fraction of the weekly sound allowance a user has received is best done in a device that includes a visual display to enable rich health communication messages to best influence user behaviour. Such a device is also best positioned to maintain or connect to a database storing the user personal health information.

Considering these principles, if a listening device is capable of communicating via a digital interface its sensitivity values, as affected by the current volume setting, these shall be used instead of the maximum permitted headphone sensitivity. Furthermore, if a listening device is capable of determining CSD increments for a whole or partial listening session and communicating that via a digital interface, a PAS shall use these values instead of or the PAD's calculation of CSD increment.

Such capabilities potentially allow making listening safer in use cases beyond the simple single music player use case. This is an area for further study.

10 Profiles

A proposed goal of profiles or different grades of PAS is to provide a means of indicating to end users the comparative accuracy of different PAS implementations, in a simple and meaningful manner, to build trust in the calculated sound dose and the resulting notifications.

11 Health communication

The 'Make Listening Safe' strategy (see Appendix I) aims to reduce the risk of hearing loss through promotion of safe listening among its target group (users of personal audio devices). In view of this, the standard for safe listening devices includes a tool that will allow people to monitor their own personal sound exposure. Such a tool shall serve the purpose of giving the choice of safe listening to the users, while maintaining good quality sound output. Along with this tool, it is important that users of devices be empowered to make the right listening choice through greater awareness and information.

For this purpose, this clause outlines health communication aspects that shall be applied for complete implementation of standards for safe listening devices.

This clause aims at informing manufacturers of personal audio devices on how to promote safe listening practices among users/consumers. Specifically, it presents evidence-based recommendations on how to communicate the risks of unsafe listening and support users/consumers in the adoption of appropriate behaviour in this field. The recommendations are informed by evidence available in peer reviewed literature or gained through the study of listening habits of the target group i.e., users of personal audio devices.

11.1 Purpose of including health communication as part of the standards for safe listening personal audio systems

The intent is to provide users with information and guidance to enable them to make safe listening choices. These include providing:

– 'Personal usage information', in order for the user to know:
  - their own listening habits (use of daily and weekly sound allowance)
  - how to use safe listening features of the specific devices;

– 'Personalized recommendations and cues for actions' for safe listening, customized based on each user's listening profile

– 'General information' on
  - safe listening and ways to practice it

- the risk associated with unsafe listening
- the risk of hearing loss due to loud sounds from sources other than the personal audio system.

This information and guidance shall be shared by default with users via their mobile devices in order to reduce the risk of hearing loss.

11.2 Key recommendations for communication as part of standards for safe listening devices

Information and messages on safe listening shall be provided through:

– the device interface[1] (wherever an appropriate audio or visual interface is available)

– instruction manuals

Information about the safe listening features of the device should be included on or in the packaging.

11.2.1 Device interface user information

Clauses 11.2.1.1 and 11.2.1.2 outline information that shall be available to the user through the device interface.

11.2.1.1 Personal usage information

Information regarding various listening parameters defining the users' listening habits shall be accessible to users in order to allow them to keep track of their exposure to sound through the device. In cases of devices with a screen, this could be through an icon on the screen. Through the icon, the user shall be able to see their use of daily/weekly sound allowance in an easy-to-understand presentation, e.g., the person may be able to view how much of the weekly sound allowance has been used and to see how their listening behaviour has been over the past seven days.

In devices without a screen, the information shall be made available through alternative means, such as audio cues or via another device with a screen.

NOTE – For such devices (without screens), feedback to the user may not be provided in real time but it can be provided at a later time.

The device (when capable) should display:

a) the average sound level for the day and week;

b) the time for which the user has listened in hours and minutes over the day and the week.

Figure 11-1 gives a non-normative example of information provided on a smartphone visual interface for safe listening.

[1] Refers to the hardware components (such as screen) that allow a user to interact with an electronic device.

Figure 11-1 – Examples of information provided on a smartphone visual interface for safe listening

11.2.1.2 Messages

The device shall provide the user with warnings and cues for action:

a) The device shall give relevant warnings and cues for actions when the user exceeds 100% of the weekly allowance. Suggestions for the development of such messages are provided in Appendix VII.

- The user shall receive first a "warning" expressed through text and visuals informing that a threshold has been reached and that from this point on, further listening at the same volume will pose a risk for his/her hearing.
- The warning shall be followed by a "cue for action" in which the user is offered the choice to either accept the risk of continued listening or protect his/her hearing. The "cue for action" should be linked to active options on the device such as:
  – automatic safe volume option, by which the device automatically changes the volume to achieve a safer listening level;
  – direct access to volume settings;
  – set up of default volume limits;
  – remind later option;
  – ignore and continue option.
- If the user fails to take any action, the volume shall automatically be reduced as described in clause 13.1 (a sound level at the DRP, with diffuse-field correction, no greater than 80 or 75 dBA (according to the mode selected)).

NOTE 1 – The timeframe for implementation of this feature by manufacturers will be in line with the recommendations made by CENELEC.

NOTE 2 – If, upon reaching 100% of the user's weekly allowance, the level is automatically reduced to 80 dBA (75 dBA for sensitive listeners), the user's sound exposure will continue to increase beyond 100%. Such an action is therefore not fully protective against further risk to hearing; rather, the intention is to ensure that listening proceeds at no more than a moderate level until the user has acknowledged the warning.

b) The device should provide relevant messages when the sound allowance usage reaches certain pre-determined levels. Refer to Appendix VII.1 for the suggested levels at which warnings/cues can be given and sample content.

Such warnings depend on the device's capability and should be multimodal, e.g., in the form of visual, vibratory or audible warnings, in order to ensure that the user's attention can be directed towards these. Figure 11-2 gives non-normative examples of messaging displayed in a smart watch.

Figure 11-2 – Example of messaging displayed in a smart watch

– Daily messages: The device should provide a daily summary message that is based on the user's listening behaviour over the past days, encouraging safe listening habits and discouraging or warning against unsafe listening habits. Examples of such messages are provided in clause VII.3.

11.2.2 General information

– When the device has a screen, information on what is safe listening and its benefits, as well as the risks posed by unsafe listening, shall be displayed on the screen.

NOTE – It is expected that the information above is accessible without the need for excessive navigation.

The availability of this information shall be indicated on the user interface (home screen) through a distinct and recognizable icon. Figure 11-3 gives a non-normative example of a safe listening icon displayed on a smartphone screen.

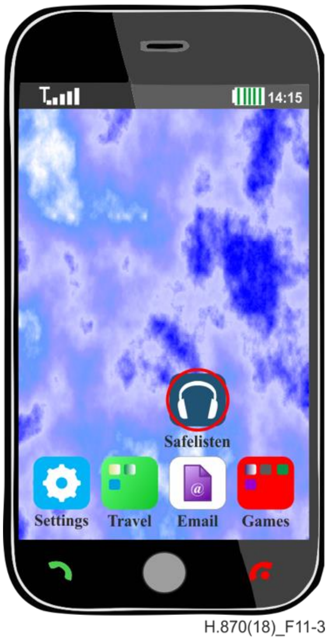


Figure 11-3 – Safe listening icon displayed on a smartphone screen

There should be a tutorial informing users of what is safe listening, what the risks are of unsafe listening, the device's safe listening features and how to use them. The screens should also include links to relevant webpages where the user can find more information. Figure 11-4 gives non-normative examples of screens linking to information on safe listening and external links.

Figure 11-4 – Examples of screens linking to information on safe listening and external links

11.2.3 Information through means other than the device itself:

11.2.3.1 User manual

The user manual shall clearly state that unsafe listening practices with the use of the device pose the risk of permanent hearing loss.

It should also give details of the volume-limiting functions and cues for action.

The user manual should also clearly outline how the allowance-assessment system works and refer to its uncertainty.

The manual should clearly indicate that information on the device does not take into account additional sources of sound exposures either from other audio devices or environmental sound exposure.

The manual could also provide information regarding hearing protections from loud environmental sounds, in order to minimize the risk of hearing loss.

11.2.3.2 Packaging

It is highly recommended that a message/warning be included on or in the external packaging of the devices. It is recommended that such a warning/message be:

– concise, simple and clear

– accompanied by a relevant illustration

– positioned on a plain background.

11.2.3.3 Website and advertising

Information on safe listening should be included on the manufacturer's website/s (e.g., supporting the device interface information, see clause 11.2.1).

Text contained on the manufacturer's website must be evidence-based and aligned to the recommendations of the WHO/ITU safe listening standards. A link to the WHO website and other relevant, reputable websites could be included.

Wherever possible, advertising of products could also provide relevant information. Such information can refer to both the potential harm to hearing through improper use of their device and the advantages of listening safely in order to maintain healthy hearing while enjoying a good listening experience.

12 Ambient noise control

Given that the listening level is tightly related to the level of the ambient noise (for example, see Figure 9 in [b-Portnuff]), the use of earphones that provide some degree of attenuation of the ambient noise leads users to choose reduced listening levels, hence diminish the overall noise exposure. This attenuation of ambient noise can be done through passive means or by involving active noise control that provides an electronic cancellation of the ambient noise [b-Berger-Voix].

12.1 Passive attenuation of the background noise

A first approach to limit the ambient noise during music listening consists in merging the features of the earphone with the noise isolation provided by a passive hearing protection device. Such earphones can be large around-the ear headphones where a hard shell and the soft cushion will ensure a proper attenuation of ambient noise. It can also come as in-ear earphones that use roll-down foam earplug tips, pre-moulded tips, or even custom moulded tips to provide a substantial amount of attenuation when properly fitted in the ear canal [b-Smith-Voix]. These products simply utilize passive attenuation and are sometimes referred to as noise-isolating headset/earphones. Their proper attenuation of ambient sounds requires a tight fit between the tip of the earphones and the wearer's ear canal, that cannot be achieved with the ubiquitous "button receiver", see intra-concha earphone in [ITU-T P.57], that only seats in the concha or at the entrance of the ear canal and does not provide any substantial attenuation.

12.2 Active noise reduction of background noise

Some earphones featuring active noise reduction (ANR) have been commercialized over the last decades as around or over-the-ear headphones as well as in-ear earphones. These ANR devices use an analogue or digital controller to generate a sound wave that is of the same magnitude but opposite phase as the initial disturbance (the ambient noise). They can quite effectively cancel or reduce the background noise in the area of the user's eardrum.

12.3 Benefits of noise-isolating earphones

The main auditory benefit of using noise isolating earphones, assuming they are properly fitted, is that they enable the wearer to lower the listening level to a safer value, as the ambient noise is partially reduced as shown in Figure 9 of [b-Portnuff] (see also [b-Voix,Cocq,Hager]). However, the proper fit of in-ear noise-isolating earphones can be difficult to achieve in the first place and/or to maintain consistently over time. Slight changes in the fit of noise-isolating earphones not only affect the amount of attenuation that these devices provide, but also affect the frequency response of the earphones and dramatically increase the uncertainty associated with the sound pressure level delivered in the occluded ear canal. This latter effect is particularly pronounced with passive in-ear earphones that rely on a perfectly sealed ear canal for superior noise isolation and optimal frequency response.

12.4 Safety concerns associated with noise-isolating earphones

Isolating earphones need to provide a high attenuation in order to be effective at reducing the ambient noise. This can also raise some concerns regarding the safety of using such isolating devices in day-to-day activities, not to mention the distraction induced by music listening itself. Indeed, noise-isolating earphones, when properly fitted, may reduce ambient noises to very low levels that may be harder to perceive. That combined with the fact that the music being played back will further mask the residual ambient noise, it is easy to understand that the auditory situational awareness will be compromised. Ambient noise with useful information, such as a person calling or a car honking, will be lost and the detection, recognition and identification of all hazardous sound sources will be compromised. Besides, the localization of the source in azimuth and elevation, as well as estimation of distance, speed and direction capabilities can all be impacted by the use of noise isolating earphones.

For this reason, it is recommended that manufacturers warn the users of the risks faced when using the PAS and accompanying earphones/headphones during activities where auditory cues can be crucial (street jogging, car driving, etc.) and where the loss of such cues could potentially endanger their physical safety.

13 Volume control

13.1 Volume limiting

The device or system shall provide the user with a suitable method for volume-limiting. This refers to a feature which provides a message relative to a predetermined reference exposure (sound allowance) limit and when this message is unacknowledged, the device or system shall automatically reduce the volume of the device to achieve a sound level at the DRP, with diffuse-field correction, no greater than 80 or 75 dBA (according to the mode selected). It is further recommended that this should be set as the default option and that the user should have the option of turning this feature off if they do not wish to use this setting.

When this is implemented, a volume limiting option message shall be automatically provided when the user reaches 100% of the weekly allowance. The user shall be given a message, which will allow them the option to "continue listening" in case they do not wish the device volume to reduce. When the message is not acknowledged, the default action will be to reduce the volume to achieve the predetermined sound level. If possible, the users should be given the option to customize this level (the level at which they would like their device to limit the volume) according to their preference.

13.2 Password-protected volume control

The device or system shall have the option whereby the maximum sound output can be fixed and locked in the settings, possibly through the use of a password.

The intent of this feature is to allow parents (or other adults) to limit the maximum sound output of the child's device, in a way that cannot be changed by the child.

The feature may also be used by individual users in order to limit their own sound exposure, if they wish to do so, by fixing the maximum output on their device.

14 Guidance on ancillary concerns

In addition to the direct effect of the transducer and the playing device in PAS themselves, there are several points that may need to be taken into account when a PAS is deemed safe. [b-ITU-T P.360] has some information in this regard.

– When a headphone or an earphone is connected, there may be an acute noise (clicks and pops) due to transients (undesirable noise) in the system.

– Certain devices, when connected or "paired" together, give off a "confirmation-sound" to indicate that the devices are successfully paired. In such a case, the sound level of the confirmation sound may need to be in the safe range.

Note that this cannot be measured by a "dosimeter" on a PAD.

Appendix I

Status report

(This appendix does not form an integral part of this Recommendation.)

WHO estimates that currently over 1.5 billion people worldwide experience some degree of hearing loss, nearly 30% of which is disabling hearing loss. It is estimated that with the current demographic trends, by 2050, there could be over 2.5 billion people with hearing loss globally. While this upward trend reflects changes in population demographics, it also underlines the need to address the preventable causes of hearing loss.

One of the main avoidable causes of hearing loss is termed as noise-induced hearing loss, which refers to hearing loss due to overexposure of ears to sound energy, including music listened to over personal audio devices and systems. WHO estimates that 1.1 billion people between 12 to 35 years of age are at risk of hearing loss due to unsafe listening practices. This makes it an issue of imminent public health concern, especially since even now, unaddressed hearing loss poses an annual global cost of USD 980 billion.

Responding to the request of its Member States in the World Health Assembly resolution-WHA70.13, WHO is working with other stakeholders to mitigate the risk of hearing loss due to unsafe listening by raising awareness and promoting safe listening behaviours. Making this change requires that users of personal audio devices or systems should be able to access devices/systems that include safe listening features.

To this end, WHO, with help from ITU, conducted a gap-analysis of standards related to safe listening. The results are found in the report at:

https://cdn.who.int/media/docs/default-source/documents/health-topics/deafness-and-hearing-loss/monograph_on_situation_analysis_and_background_for_standards_for_safe_listening_systems.pdf?sfvrsn=336b9823_5.

Other related background documents on the "Making Listening Safe" initiative can be found at https://www.who.int/activities/making-listening-safe, with an overview at https://itu.int/en/ITU-T/studygroups/2017-2020/16/Documents/Safe_listening_initiative_background_201804.docx.

Following the launch of version 1 of this standard, few business entities have implemented some of its recommendations, which are providing essential information on and options for safe listening to their users. The second version of this standard will ensure its applicability to a wider range of devices and offer more safe listening features to people, in an effort to promote safe listening and mitigate the growing risk of hearing loss globally.

Appendix II

Dose estimation functionality for implementation in a personal audio system

(This appendix does not form an integral part of this Recommendation.)

II.1 Introduction

This appendix describes an example of how a dosimeter can be implemented in a personal audio system (PAS) when measuring the digital media signal and considering known or assumed properties of headphones. It is based on the equal energy principle in hearing impairment risk assessments, where the squared A-weighted sound pressure, integrated over the exposure time, constitutes the dose.

The uncertainties involved in such dose estimations (e.g., confidence interval) are also discussed.

II.2 Main related standards

[EN 50332-3] describes a dose measurement system in a personal media player (PMP) and this appendix is intended only as supplementary information to that standard.

[IEC 61252] describes acoustic dosimeters to be worn on the body.

II.3 Definition of dose in the context of acoustic dosimetry

$$dose = \int_{t1}^{t2} (p_A(t))^2 dt$$

where p_A is the A-weighted and diffuse-field corrected sound pressure.

For example, the dose acquired when being subjected to 80 dBSPL, exposure duration of 40 h is calculated as follows:

– The RMS sound pressure is $10^{\frac{80}{20}} \cdot \frac{20\mu Pa}{1Pa} = 0.2\ Pa$. Accordingly, the dose is $0.2^2 \cdot 40 = 1.6\ Pa^2h$.

Such a specific dose may be defined as a reference dose and the measured exposure estimation during a certain period may be expressed as a percentage of this reference dose. [EN 50332-3] defines the dose explained above as a 100% CSD. Furthermore, it considers only the dose acquired during a rolling 7 days.

II.4 Weighting of different frequencies

The potential hearing damage of interest for the dose estimation occurs in the cochlea in the inner ear, see Figure II.1 for reference. It would be intuitive that measurements were corrected to reflect directly the excitation of the hair cells in the cochlea. However, the vast majority of research on noise-induced hearing loss is based on sound level meter readings in the "free field" in e.g., factories (strictly speaking typically something between free field and diffuse field conditions). Therefore, risk assessment and action limits are based on such readings. Although the A-weighting was not developed specifically for hearing loss risk assessment, research has shown that sound level meter readings in the free field correlate reasonably well with observed noise-induced hearing loss, when the squared A-weighted sound pressure is integrated over the exposure time.

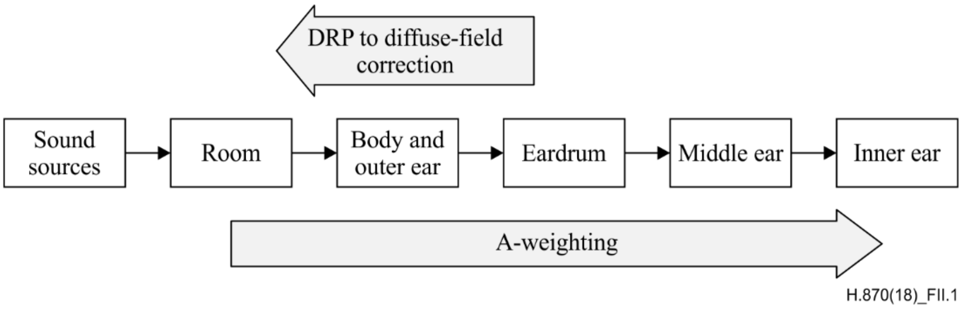


Figure II.1 – Conceptual view of the roles of the different corrections used in measurements, to give certain weightings to various frequencies

When the earphone/headphone/headset characteristics are measured at the eardrum reference point (DRP) using a head and torso simulator, the diffuse-field correction transforms the measurement to a quantity comparable with typical sound level meter readings in the free/diffuse field. Since the original research included sound sources from a variety of incidence angles to the workers' ears, no specific incidence angle (e.g., free-field correction for frontal incidence at an elevation of 0 degrees) is assumed in the risk estimation, rather the diffuse-field correction is used, as an average representation of various incidence angles.

Figure II.2 shows A-weighting and DRP to diffuse-field weighting.

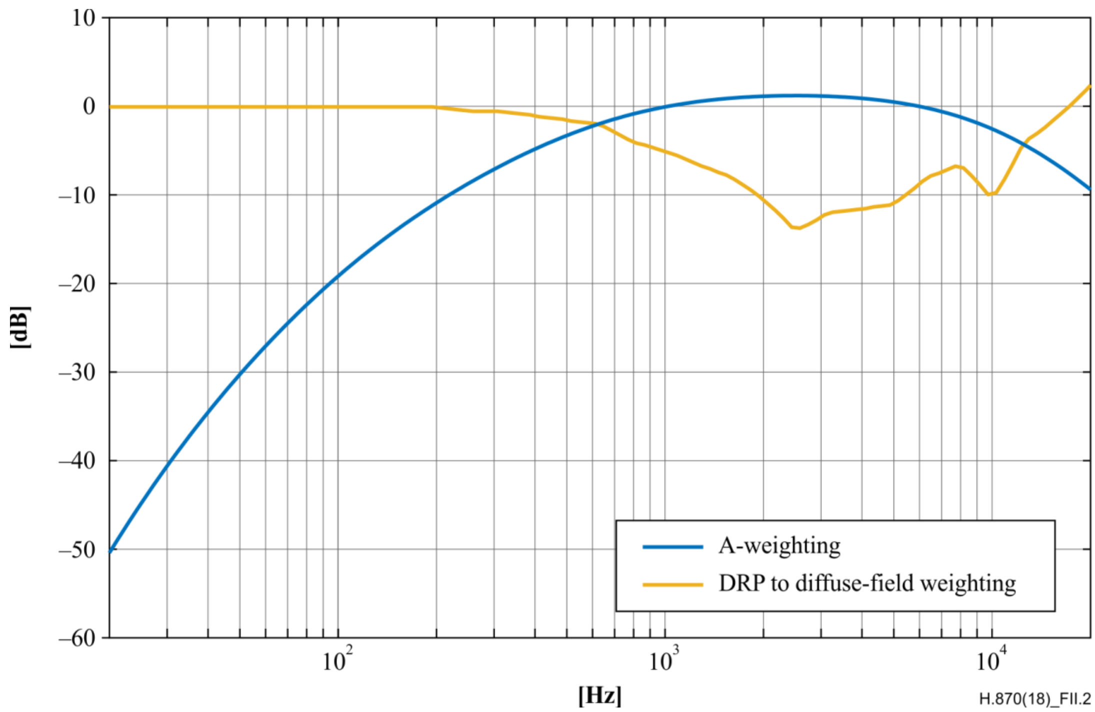


Figure II.2 – A-weighting [IEC 60268-1] and DRP to diffuse-field correction/weighting [ITU-T P.58]

II.5 Signal capture point in a personal audio system (PAS)

Figure II.3 contains an example of an audio player system and preferred dosimeter capture point where the measured signal x is collected just before digital-to-analogue conversion.

Since p_A is typically not readily available, it is shown here how to estimate p_A based on a digital signal in the player (PAD, personal audio device, which does not have a transducer) and other known or assumed characteristics of PAD and headphones.

Table II.1 describes the quantities needed for dose estimation.

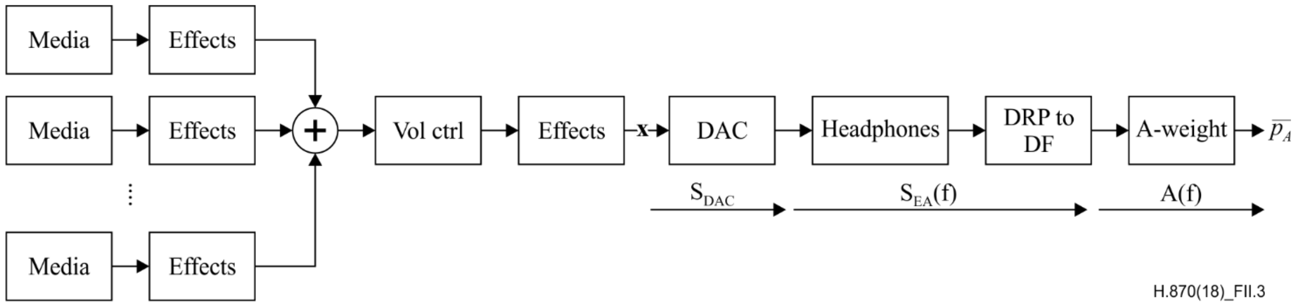


Figure II.3 – Example of audio player system and preferred dosimeter capture point

Table II.1 – Quantities needed for dose estimation

Quantity	Description	Unit
x_L and x_R	Digital signals for the left and right channels, taken in the PAS audio system after the summation of all audio sources, after volume control and after all audio processing.	sample value
S_{DAC}	Sensitivity of the digital-to-analogue converter and subsequent analogue circuitry. In case the headset has a digital input, this parameter is attributed to the headset rather than the player.	Volt/sample value
S_{EA}(f)	Electro-acoustic sensitivity of the headphones, measured at the eardrum reference point (DRP) and then corrected using DRP to diffuse-field correction for the frequency range 20 to 20 kHz. See [ITU-T P.381] for the measurement method of headset receiving frequency response, [ITU-T P.58] for diffuse-field correction and [ITU-T P.380] for additional information such as five times re-seating and averaging.	Pascal/Volt
A(f)	A-weighting filter network, see [IEC 61672-1] for a general specification and [IEC 61252] for a dosimeter design goal.	Volt/Volt
T	Duration of the segment.	Hours

II.6 Handling of left and right channels

For simplicity, and based on some measurements, in implementation and interpretation of results, the power average of the left and right channels is used for a single dose estimation (see [b-SG16-R17]).

II.7 Dosimeter implementation example

For a discrete time, segment-based implementation, the estimation of a daily/weekly dose can be implemented accordingly, in time or frequency domain:

1) Acquire n samples per channel of the signal x, (typically over a 1 second time window). Filter the signal to consider DAC, headphone and A-weighting.

$$z(k) = filter(x(k), [S_{DAC} \cdot S_{EA}(f) \cdot A(f)])$$

2) Calculate the mean power of the left and right channels and multiply by the duration of the segment.

$$\underline{dose_{segment}} = T \cdot \frac{1}{n} \sum_{k=1}^{n} \frac{1}{2} \left({z(k)_L}^2 + {z(k)_R}^2 \right)$$

3) Add the dose contribution to the previously accumulated dose estimate.

$$\underline{dose_m} = \underline{dose_{m-1}} + \underline{dose_{segment}}$$

4) (Optional): Present the dose reading for the present day and the previous 6 days.

5) (Optional): Express the total dose as a percentage of the reference dose.

6) If midnight has passed: store the dose for the concluded day, reset the daily dose to zero and measure for the new day.

NOTE – The storage of the cumulating dose shall have sufficient accuracy to avoid nulling small portions from a single segment.

II.8 Handling of computational complexity

To save calculation resources and increase battery time, the signals may be decimated (without anti-aliasing filters). Care shall be taken that the accuracy remains sufficient, for music and speech signals. Care shall also be taken that the filtering remains appropriate, for the decimated signal.

Filtering implementations may be simplified to a certain extent.

II.9 Handling of dose over days and weeks

It is recommended to store each day's dose estimate during a rolling 7-day period. The accumulated dose during the present day and the six previous days is compared to the reference dose explained in clause II.3.

Figure II.4 shows an example of accumulation of dose over 7 days, constituting in total 1.6 Pa^2h, hence 100% calculated sound dose.

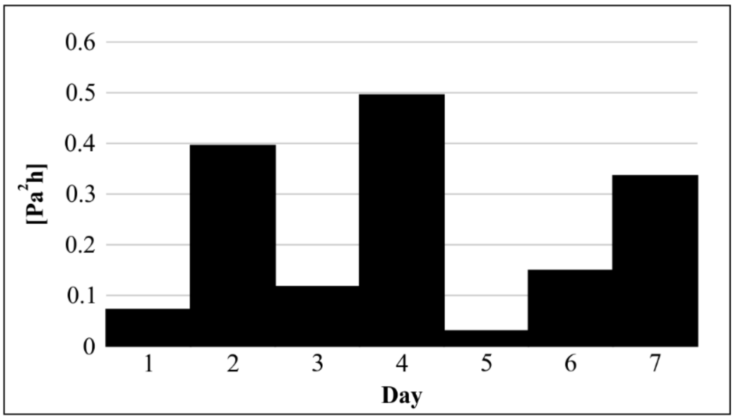


Figure II.4 – Example of accumulation of dose over 7 days, constituting in total 1.6 Pa^2h, hence 100% CSD

II.10 Case of unknown headphone characteristics

In many cases, the headphone type may not be known to the player and its sensitivity can vary significantly, as illustrated in Figure II.5. In such a case, the dosimeter assumes:

– maximum permitted headphone sensitivity, meaning a simulated programme signal characteristic voltage (SPCV) of 75 mV, see [EN 50332-2] and [ITU-T P.381];

– flat frequency response after diffuse-field correction;

– headset impedance 32 Ω (relevant when identifying S_{DAC}).

This means that $S_{EA}(f)$ is set to a constant of 12.55 Pascal/Volt.

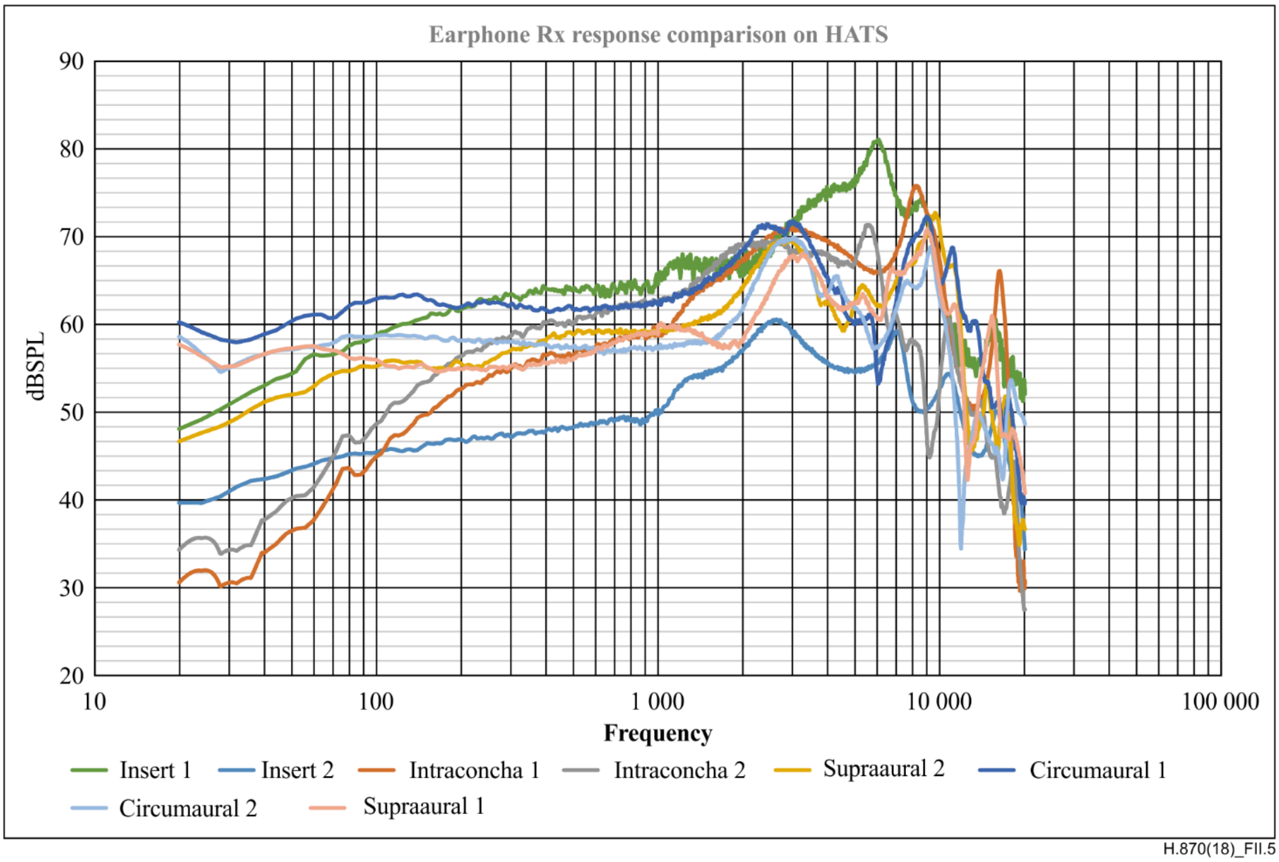


Figure II.5 – Illustration on the variability of sensitivity for nine headphones and earphones

Table II.2 shows headset characteristics at maximum permitted sensitivity according to [EN 50332-2], in 1/3-octave bands.

Table II.2 – Illustration of headset characteristics at maximum permitted sensitivity

Programme simulation noise			**Headset response**			**A-weighting**			**A-weighted acoustic**		
IEC 60268-1 (adjusted for 75 mV)			Flat DF-corrected response SPCV = 75 mV; [EN 50332-2]			[IEC 61672-1]			[EN 50332-1]		
[Hz]	PSM [dBV]	PSM [V^2]	[Hz]	[dBPa/V]	[Pa/V]	[Hz]	[dB]	[gain]	[Hz]	[dBPa]	[Pa^2]
20	–48.56	1.39E-05	20	25.10	12.55	20	–50.40	–2.52E+01	20	–73.85	4.12E-08
25	–45.26	2.98E-05	25	25.10	12.55	25	–44.82	–2.24E+01	25	–64.98	3.18E-07
31.5	–42.46	5.68E-05	31.5	25.10	12.55	31.5	–39.53	–1.98E+01	31.5	–56.89	2.05E-06
40	–40.26	9.43E-05	40	25.10	12.55	40	–34.54	–1.73E+01	40	–49.70	1.07E-05
50	–38.56	1.39E-04	50	25.10	12.55	50	–30.28	–1.51E+01	50	–43.73	4.24E-05
63	–37.36	1.84E-04	63	25.10	12.55	63	–26.22	–1.31E+01	63	–38.48	1.42E-04
80	–36.46	2.26E-04	80	25.10	12.55	80	–22.40	–1.12E+01	80	–33.75	4.21E-04
100	–35.96	2.54E-04	100	25.10	12.55	100	–19.15	–9.57E+00	100	–30.00	1.00E-03
125	–35.56	2.78E-04	125	25.10	12.55	125	–16.19	–8.10E+00	125	–26.65	2.16E-03
160	–35.26	2.98E-04	160	25.10	12.55	160	–13.25	–6.62E+00	160	–23.40	4.57E-03
200	–35.16	3.05E-04	200	25.10	12.55	200	–10.85	–5.42E+00	200	–20.90	8.12E-03
250	–35.06	3.12E-04	250	25.10	12.55	250	–8.68	-4.34E+00	250	–18.63	1.37E-02
315	–35.06	3.12E-04	315	25.10	12.55	315	–6.64	-3.32E+00	315	–16.60	2.19E-02

Table II.2 – Illustration of headset characteristics at maximum permitted sensitivity

Programme simulation noise			**Headset response**			**A-weighting**			**A-weighted acoustic**		
IEC 60268-1 (adjusted for 75 mV)			Flat DF-corrected response SPCV = 75 mV; [EN 50332-2]			[IEC 61672-1]			[EN 50332-1]		
[Hz]	PSM [dBV]	PSM [V^2]	[Hz]	[dBPa/V]	[Pa/V]	[Hz]	[dB]	[gain]	[Hz]	[dBPa]	[Pa^2]
400	–35.06	3.12E-04	400	25.10	12.55	400	–4.77	–2.39E+00	400	–14.73	3.37E-02
500	–35.06	3.12E-04	500	25.10	12.55	500	–3.25	–1.62E+00	500	–13.20	4.78E-02
630	–35.06	3.12E-04	630	25.10	12.55	630	–1.91	–9.54E-01	630	–11.86	6.51E-02
800	–35.06	3.12E-04	800	25.10	12.55	800	–0.79	–3.97E-01	800	–10.75	8.41E-02
1000	–35.16	3.05E-04	1000	25.10	12.55	1000	0.00	0.00E+00	1000	–10.06	9.87E-02
1250	–35.36	2.91E-04	1250	25.10	12.55	1250	0.58	2.88E-01	1250	–9.68	1.08E-01
1600	–35.66	2.72E-04	1600	25.10	12.55	1600	0.99	4.97E-01	1600	–9.56	1.11E-01
2000	–36.06	2.48E-04	2000	25.10	12.55	2000	1.20	6.01E-01	2000	–9.75	1.06E-01
2500	–36.66	2.16E-04	2500	25.10	12.55	2500	1.27	6.36E-01	2500	–10.28	9.37E-02
3150	–37.56	1.76E-04	3150	25.10	12.55	3150	1.20	6.01E-01	3150	–11.25	7.49E-02
4000	–38.76	1.33E-04	4000	25.10	12.55	4000	0.96	4.82E-01	4000	–12.69	5.38E-02
5000	–40.16	9.65E-05	5000	25.10	12.55	5000	0.56	2.78E-01	5000	–14.50	3.55E-02
6300	–42.06	6.23E-05	6300	25.10	12.55	6300	–0.11	–5.70E-02	6300	–17.07	1.96E-02
8000	–44.46	3.58E-05	8000	25.10	12.55	8000	–1.14	–5.72E-01	8000	–20.50	8.91E-03
10000	–46.96	2.02E-05	10000	25.10	12.55	10000	–2.49	–1.24E+00	10000	–24.34	3.68E-03
12500	–49.86	1.03E-05	12500	25.10	12.55	12500	–4.25	–2.12E+00	12500	–29.01	1.26E-03
16000	–53.26	4.72E-06	16000	25.10	12.55	16000	–6.70	–3.35E+00	16000	–34.86	3.27E-04
20000	–56.66	2.16E-06	20000	25.10	12.55	20000	–9.34	–4.67E+00	20000	–40.90	8.13E-05
	total [V^2]	5.63E-03								total [Pa^2]	9.97E-01
	total [V]	**7.50E-02**								total [Pa]	9.99E-01
										total dBSPL	**9.40E+01**

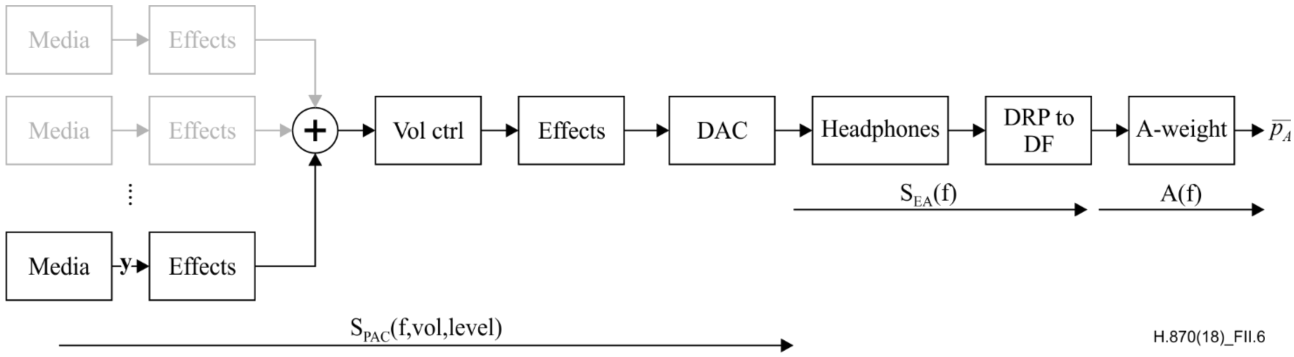
NOTE – An [IEC 60268-1] programme simulation noise signal of 75 mV generates a sound pressure level of 94 dBSPL(A).

II.11 Alternative audio signal capture point

When the implementation shown in Figure II.3 is not feasible, a simplified dosimeter may be implemented as follows.

In case the signal is captured at a point further from the output of the device (e.g., inside a specific media application which can access only its own media stream), the influence of the downstream digital audio system such as volume control and sound effects have to be accounted for by a best-effort approach. The system identification of S_{PAD} across volume control settings, may have to be performed at multiple content levels, to account for possible non-linear processing.

Figure II.6 shows an example of a player audio system in the case where the signal y is captured inside a specific media source application.



NOTE – The influence of volume control and sound effects have to be accounted for by a best-effort approach. The characteristics of the player are functions of frequency, volume control setting and potentially the level of the content.

Figure II.6 – Example of player audio system in cases where the signal *y* is captured inside a specific media source application

Refer to clause 8.1.3.

II.13 Uncertainties

Refer to clause 7.2.

Appendix III

European Standard EN 71-1 for toys

(This appendix does not form an integral part of this Recommendation.)

European Standard [b-EN 71-1] clause 4.20 "Acoustics" specifies requirements that are also applicable to tape players, CD players and other similar electronic toys when they are provided with headphones or earphones. In particular:

"… a) The A-weighted emission sound pressure level, *Lp*A, produced by *close-to-the-ear toys* shall not exceed 80 dB when measured in a free field. The A-weighted emission sound pressure level, LpA , produced by close-to-the-ear toys shall not exceed 90 dB when measured using an ear coupler.

… e) The C-weighted peak emission sound pressure level, *Lp*C peak, produced by any type of toy excluding toys using percussion caps shall not exceed 115 dB.

… f) If the C-weighted peak emission sound pressure level, *Lp*C peak, produced by a toy exceeds 110 dB, the potential danger to hearing shall be drawn to the attention of the user by a warning (see 7.14)."

NOTE – Clause 8.28 of [b-EN 71-1] specifies the method to be used for determination of emission sound pressure level in toys.

Clause 7.14 of [b-EN 71-1] "Acoustics" prescribes that toys which produce high impulse sound levels, or their packaging shall carry the following warning: "*Warning. Do not use close to the ear! Misuse may cause damage to hearing.*"

Clause A.25 of [b-EN 71-1] "Acoustics" alerts that "the sensitivity of children to loud noise is basically unknown. However, there are scientists who hold the opinion that since the auditory canal in children is smaller than in adults, there is a different amplification which makes children more sensitive to high-frequency sounds. Impulse sounds are especially hazardous since it is very difficult for the human ear to determine the sound levels due to the very short time factor. It is a fact that permanent damage to hearing may occur after only one exposure to high peak sound levels."

Appendix IV

"Music" versus "noise"

(This appendix does not form an integral part of this Recommendation.)

The following is taken from [b-Neitzel and Fligor]:

Lindgren and Axelsson (Lindgren and Axelsson 1983) examined 10 subjects in a study of temporary threshold shift (TTS) resulting from exposures to non-musical noise and found that these exposures resulted in TTS severity that exceeded those from musical noise of the same duration and overall A-weighted sound pressure level. Four of the subjects experienced essentially the same TTS from both sources, while six experienced greater TTS from the non-musical exposure than from the musical exposure. This provides some evidence that the content of sound and the resulting subjective perceptions of exposure may affect the risk of TTS. In a separate study, Axelsson and Lindgren (Axelsson and Lindgren 1981) documented TTS effects among musicians that were less than those of audience members.

Strasser, Erle, and Legler (Strasser et al. 2003) also studied 10 subjects over three energetically equivalent exposures to music and non-music sound over three days. Classical music (2 h exposure, mean 91 dBA) was found to be associated with substantially less TTS (10 dB vs. 25 dB) compared to industrial noise of the same duration and mean level, as well as an energetically equivalent industrial level (94 dB for 1 h) and which recovered much faster (100 min vs. 800 min). As with the Lindgren and Axelsson study, this study suggests that the content of sound may affect the risk of TTS.

Strasser, Irle, and Scholz (Strasser et al. 1999) examined four energetically similar exposures (94 dB for 1 hr): white noise, industrial noise, heavy metal music and classical music. Industrial noise and heavy metal music were found to induce a similar amount of TTS and to require similar durations of time to recover (i.e., restitution time). However, classical music was found to result in less TTS and shorter restitution times than industrial noise, heavy metal music, or white noise. As with the previous studies, this study highlights potentially different consequences of exposure to classical music than to other types of music and industrial noise.

Mostafapour 1998 (Mostafapour et al. 1998) prospectively examined hearing loss among 50 university student subjects (mean age 22.1 years). They compared noise exposures (assessed via self-reported participation in a number of occupational and non-occupational events, as well as firearms use) to observed degree of hearing loss. The authors noted no association between qualitative exposure to any of the assessed sources of noise and presence of a noise notch (determined via pure tone audiometry), and determined that there was low risk of NIHL among the subjects.

Finally, Swanson et al (Swanson et al. 1987) exposed 20 male subjects to music and noise of approximately equivalent energy (about 106 dBA) and for the same 10-min duration. Both exposures resulted in a significant post-exposure audiometric TTS at 4 and 6 kHz. TTS was significantly greater from music exposures among subjects who reported disliking the music used in the experiment. This study further supports the notion that subjective factors related to music may influence the risk of hearing loss resulting from music exposure, though it should be noted that audiometric testing involves a cognitive element that could conceivably be negatively influenced/biased by fatigue, loss of motivation, or frustration.

Appendix V

On stapedius muscle reflex

(This appendix does not form an integral part of this Recommendation.)

Stapedius muscle reflex (SMR), also known as acoustic middle ear reflex, is the process in which the stapedius and tensor tympani muscles of the ossicles contract when the ear is exposed to high intensity sound. This reflex has been extensively studied [b-Moller 1995]. Contraction of the stapedius muscle reduces sound transmission through the middle ear. It is believed, therefore, that this mechanism is in place, among other things, in order to decrease the transmission of vibrational energy to the cochlea. The threshold of the human acoustic middle ear reflex is approximately 85 dB above the normal hearing threshold though there are considerable individual variations. [b-Moller 2013].

Appendix VI

Consideration of recovery phase

(This appendix does not form an integral part of this Recommendation.)

There is an accumulation phase and there is a recovery phase in the auditory system. The current dosimetry for an occupational setting does not take this into account. There are cases where sleeping quarters are not quiet (ships), in that case the sleeping is not considered "quiet" and the details are for future study. More information is needed.

Acoustic trauma is a single exposure to sound resulting in immediate injury to the auditory system. It is sometimes called sound injury.

Generally, the threshold level for acoustic trauma is accepted as 200 Pa or 140 dB SPL (peak). The literature suggests that in highly susceptible individuals, this threshold might be as low as 79.6 Pa or 132 dB SPL (peak) [b-Price 1981].

Sound-induced auditory injury is known to follow a dose-effect relationship. Sound "overdose" results in metabolic overload, leading to apoptosis of structures in cochlea and primary auditory nerve fibres.

Well established damage risk criteria in workplace noise exposure studies show that:

– 85 dBA for 8-hour daily exposure, 40-hr weekly exposure over working lifetime (5.06 Pa2h) (8% at risk for "material hearing impairment");
– 90 dBA for 8-hour daily exposure, 40-hr weekly exposure over working lifetime (16 Pa2h) (25% at risk for "material hearing impairment").

Single-number level limiting ignores well-established science.

[b-Nixon-Glorig 1961] demonstrates that, after two years of exposure, permanent hearing loss starts to develop at 4 kHz for the group exposed to 92 dBA and already after four months for the group exposed to 97 dBA. Figure VI.1 adapted from [b-Nixon-Glorig 1961] shows noise-induced permanent threshold shifts (NIPTS) plotted against years of occupational exposure to noise for workers at three levels of noise. These threshold shifts have been corrected for the changes with age found in persons without occupational exposure to noise. The graphs are for a test tone of 4 kHz and the data points are medians. The average A-weighted sound levels were 83 dB for group A, 92 dB for group B and 97 dB for group C.

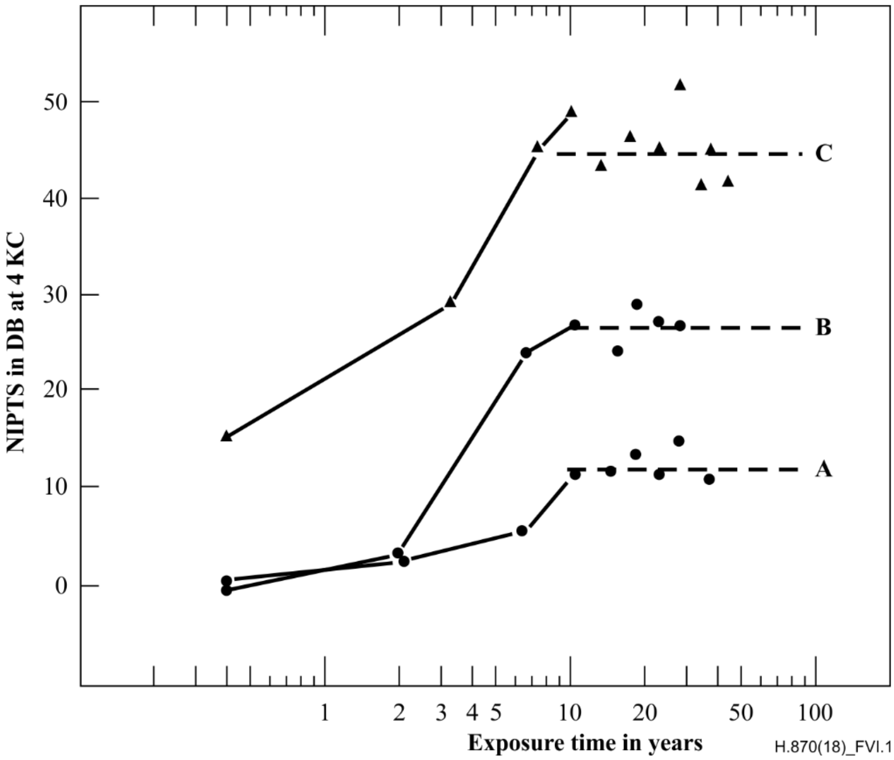


Figure VI.1 – Noise-induced permanent threshold shifts (NIPTS) plotted against years of occupational exposure to noise for workers at three levels of noise

Appendix VII

Example of health communication

(This appendix does not form an integral part of this Recommendation.)

VII.1 Recommendations to develop warnings and cues for action messages for device interfaces

The messages should be developed in consideration of the factors mentioned above. Messages should aim to gain attention, build interest and encourage users to practice safe listening. They should share actionable information, provide viable alternative behaviours and facilitate safe listening practices.

Points to consider while developing such messages/cues are (see examples in clause VII.4):

– They should clearly convey the benefits of safe listening and the risks of not doing so.

– There should be 3-4 variations of each message that can convey the information in a non-repetitive manner, designed to address a wide audience.

– Texts should use plain and clear language that is jargon-free and written below the 8th grade level to ensure that they can be understood by the majority of users.

– Some messages should be positively and others negatively worded (refer to clause VII.4.3 for examples).

– Written information should be complemented by pictorial information for ease of understanding.

– The messages shall be based on recommendations from a credible source.

– Wherever possible, the messages should be pre-tested by the manufacturer before use.

VII.2 Suggested flow (an example) of information as part of standards for safe listening devices

Figure VII.1 contains a suggested flow (an example) that aims to explain how the communication aspects of this Recommendation can be implemented within the devices.

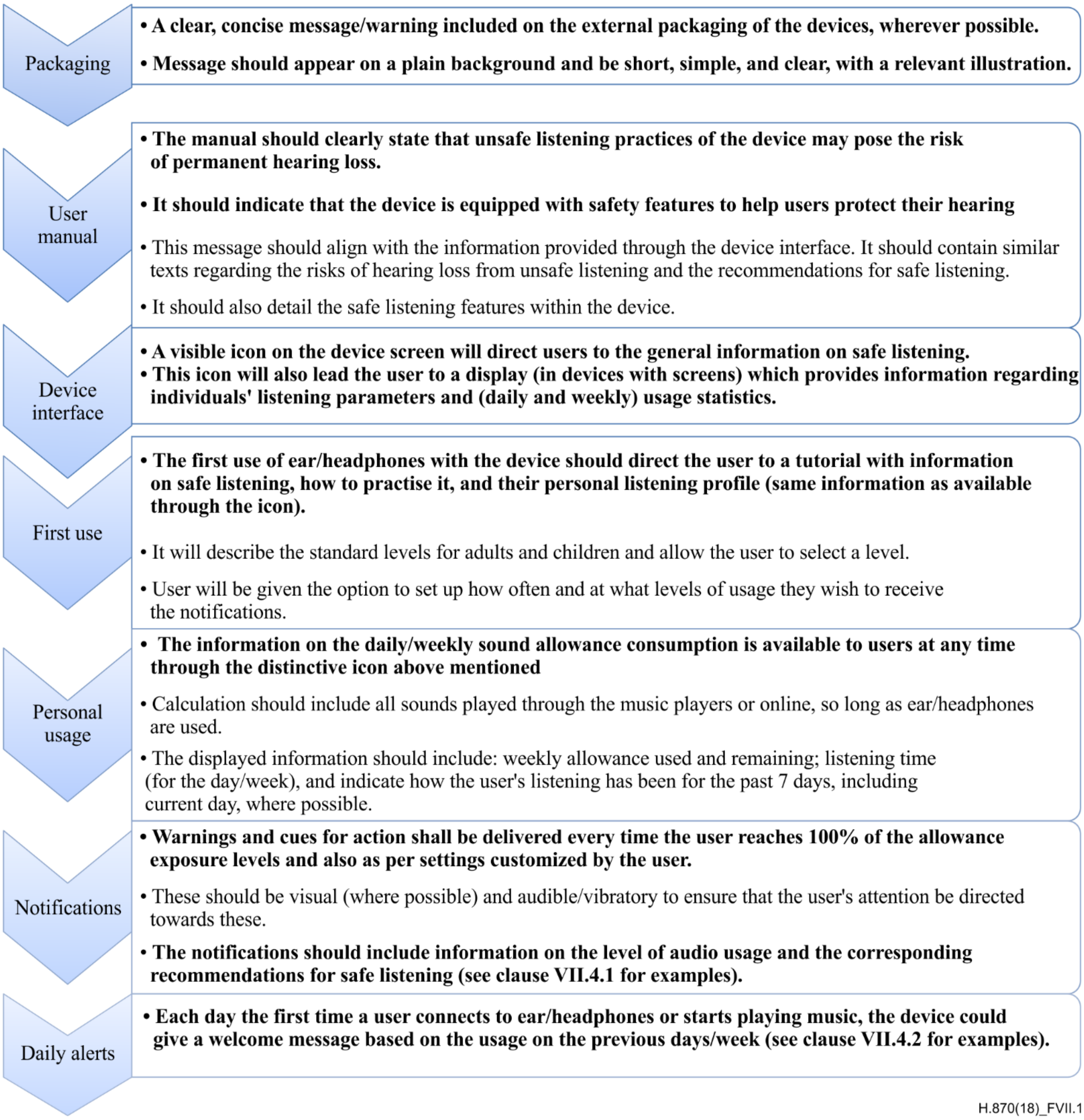


Figure VII.1 – Flow of information as part of standards for safe listening devices

VII.3 Example of how the information on listening parameters can be conveyed to the user

Through a clearly recognisable icon, users should be able to access a "dedicated space (screen)" on the device where information on the user's listening habits is stored, visualized and interpreted. In this space, the user will access a graphic representation of his/her overall listening habits or patterns and learn if (and what type of) unsafe listening practices have occurred. The visualization of the user's listening habits will include:

– graphic display of the use of weekly sound allowance;
– graphic display of daily sound exposure through a colour-coded display;
– duration of listening, over each day and the past 7 days in hours and minutes.

VII.3.1 Information on use of weekly allowance

Use of weekly allowance can be graphically conveyed as illustrated in Figure VII.2.

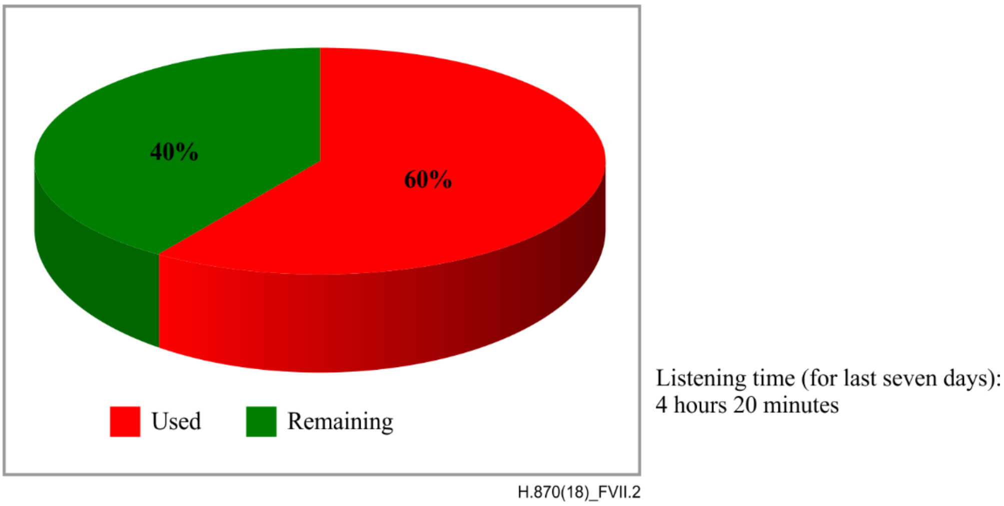


Figure VII.2 – Illustration of how graphically conveying the use of a weekly allowance

VII.3.2 Information on how the user has used the allowance on any day

For the purpose of this display, the maximum daily allowance will be equal to weekly allowance divided by 7 (approx. 15% of the weekly allowance).

Usage for the last 7 days (including the present day) would be indicated by a range of colours depicting different levels of usage, e.g., deep red for over 100% use and green when use is below 50%.

For the purpose of this communication, each day would be considered as a separate unit and colour coding for the day would not take the previous days' exposure into account. Hence, the user would start with green icon each day, irrespective of the usage pattern over past days.

VII.3.3 Listening time

Information on the overall time the user spent listening to audio content through the device each day, will also be displayed as shown in Figure VII.3.

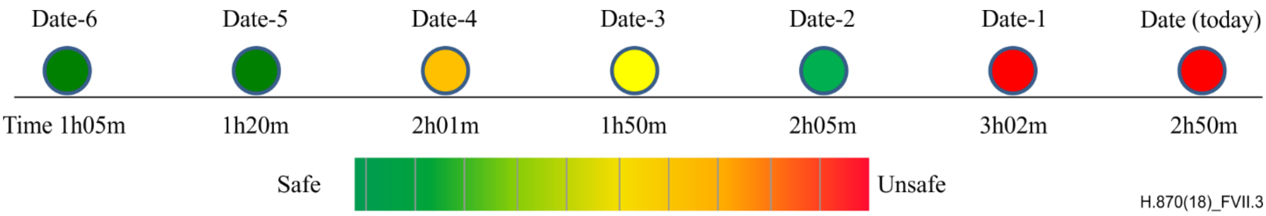


Figure VII.3 – Information on the overall daily time the user spent listening to audio content

VII.4 Warnings and cues for actions

This clause provides some examples of warnings and cues for action for the safe listening features.

VII.4.1 Examples of warnings and cues based on weekly use

Information when user reaches:

a) 80% of weekly allowance: friendly warning message

- *You have already spent* **80%** *of your allowance. Turn down the volume to protect your hearing.*
- *Reduce volume/Stop listening/Ignore warning/ go to personal usage information*

OR

- *Hello! It looks like you have been playing a lot of loud music lately. Why don't you take a short break to protect your hearing.*
- *Reduce volume/Stop listening/Ignore warning/ go to personal usage information*

b) 100% of weekly allowance: warning message (with an option to pause listening immediately)

- *You are now* **OVER 100%** *of your safe listening allowance. Unsafe listening poses a risk to your hearing.*
- *Reduce volume/Stop listening/Ignore warning/ go to personal usage information*

OR

- *Hey! You have played too much loud music recently. Take a break and protect your hearing.*
- *Reduce volume/Stop listening/Ignore warning/ go to personal usage information*

Unless the user accepts to 'ignore warning' or to 'pause listening', the default will reduce the volume to achieve a pre-specified moderate sound level (equivalent to 80 or 75 dBA).

VII.4.2 Examples of messages based on daily use

Daily message (when opening the app or at player page) which should be based on the user's use of sound allowance over the last few days:

a) Mostly in green (where the user stays below 50% weekly usage most days, not exceeding the allowance on any day): encouraging messages

- *Good job. This is the way to listen well*

OR

- *Good job! Keep playing music safely for endless fun.*
- *Well done. Keep listening safely and have endless fun.*

b) Mostly green or yellow/orange (where the user stays below 80% on most days, not exceeding the allowance on any day):

- *Be careful and listen safely.*
- *Hey! It seems that sometimes you enjoy high volume! Be careful and protect your hearing for endless fun!*
- *You can listen safely for longer by lowering the volume.*

c) Mostly yellow/orange with occasional red (where the user is not exceeding the allowance on any day):

- *Be careful! Keep the volume down to listen safely for longer*
- *Hey! It seems that sometimes you enjoy loud music! Be careful and protect your hearing for endless fun!*
- *Hey! You should watch how you listen.*

d) Mostly red (exceeding the allowance on most days):

- *You are putting your hearing at risk. Keep the volume low to listen safely*
- *Hey! You need to watch how you listen. Turn it down.*
- *Hey! It seems that you enjoy really loud music! Don't put your hearing at risk and have endless fun.*

VII.4.3 Examples of messages with positive versus negative frame; and emotional versus rational appeal

Positive frame

– **You exceeded your daily allowance for safe listening**. *Keeping the volume low lets you listen safely for longer without risk to hearing. Turn it down*.

Negative frame

– **You exceeded your daily allowance for safe listening**. *If you keep listening this way, you risk damaging your hearing forever. Turn it down*.

Rational appeal

– *The evidence says that if you listen to music above the 80 dBA SPL, for 8 hours or its equivalent, you might damage your hearing forever. Turn down the volume*.

Emotional appeal

– *Once you lose your hearing, it will not come back. Listen safely. Turn down the volume*.

Appendix VIII

Mechanism of hearing and impact of impact of sound

(This appendix does not form an integral part of this Recommendation.)

This clause gives background information for safe listening.

VIII.1 Sound and waves

Sound is a wave in a medium, such as air, produced by a vibrating body. Waves transmit energy without transmitting matter. A sound wave is a longitudinal wave, i.e., the direction of motion that creates the wave is the same as the wave motion. Waves propagate in a medium by displacing differences in force or pressure from one place to another. In particular, the transmission or propagation of energy in the sound-conducting medium is in the form of alternate compressions and rarefactions of the medium. At a certain point in time, there are interleaving compressions and rarefactions in the medium, which in turn produce variations in pressure. When air is compressed, the pressure is higher than the atmospheric pressure and when it is rarefied, the pressure is lower.

The magnitude of compression and rarefaction in the propagating medium determines the intensity of the sound, while how often the compressions and rarefactions alternate determines the frequency of the sound. Energy from the motion of sound waves flows through the eardrums and into the inner ear, where it registers as sound. Intensity I is the energy E per unit of time t that is flowing across a surface of unit area a, or I is power flowing across the surface of area a.

A pure tone is a simple sound whose pressure variations are sinusoidal in form, which is called in acoustics as the sine wave. The sine waves are periodic.

The speed of a sound wave depends on the nature of the sound-conducting medium. The speed of sound waves depends somewhat on the temperature of the air. At room temperature (20°C) the speed is 344 metres per second (m/s), corresponding to 1238 km/h.

VIII.2 Mechanism of hearing and hearing loss

As shown in Figure VIII.1, the ear is comprised of three parts: the outer ear, the middle ear and the inner ear. The middle ear consists of the tympanic membrane (also called eardrum) that terminates the ear canal and three small bones (collectively called ossicles): the malleus, incus and stapes. Two small muscles, the tensor tympani muscle and stapedius muscle are also in the middle ear. The inner ear is the innermost part of the ear and consists of the cochlea, the vestibular apparatus and the vestibulocochlear nerve. "Sound" can be considered as a series of vibrations. These vibrations arrive at an ear and are captured by the pinna. Sound travels as a wave into the ear canal down to the eardrum, which vibrates and converts the wave into mechanical energy. The ear canal has a length of approximately 2.5 cm and a diameter of approximately 0.6 cm. The sound (or its mechanical energy) then passes through the ossicles in the middle ear cavity.

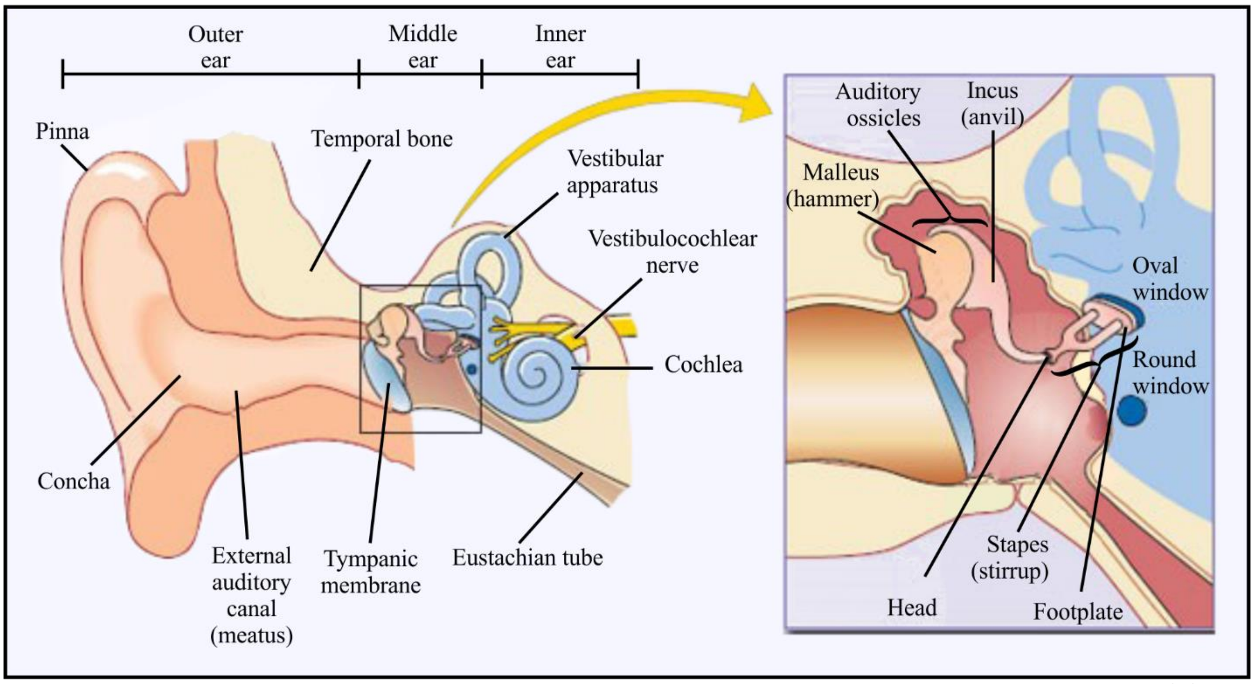


Figure VIII.1 – Illustration of the human ear

These bones amplify the mechanical energy which is transferred to the inner ear through the oval window of the cochlea (inner ear). The stapes taps on the oval window causing vibration of the fluid in the inner ear and this movement passes through the fluid-filled cochlea.

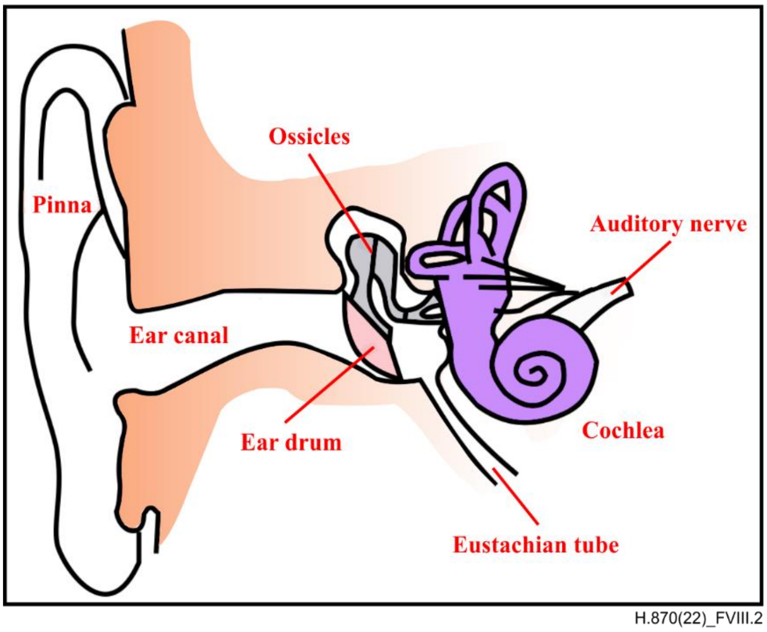


Figure VIII.2 – Ear canal

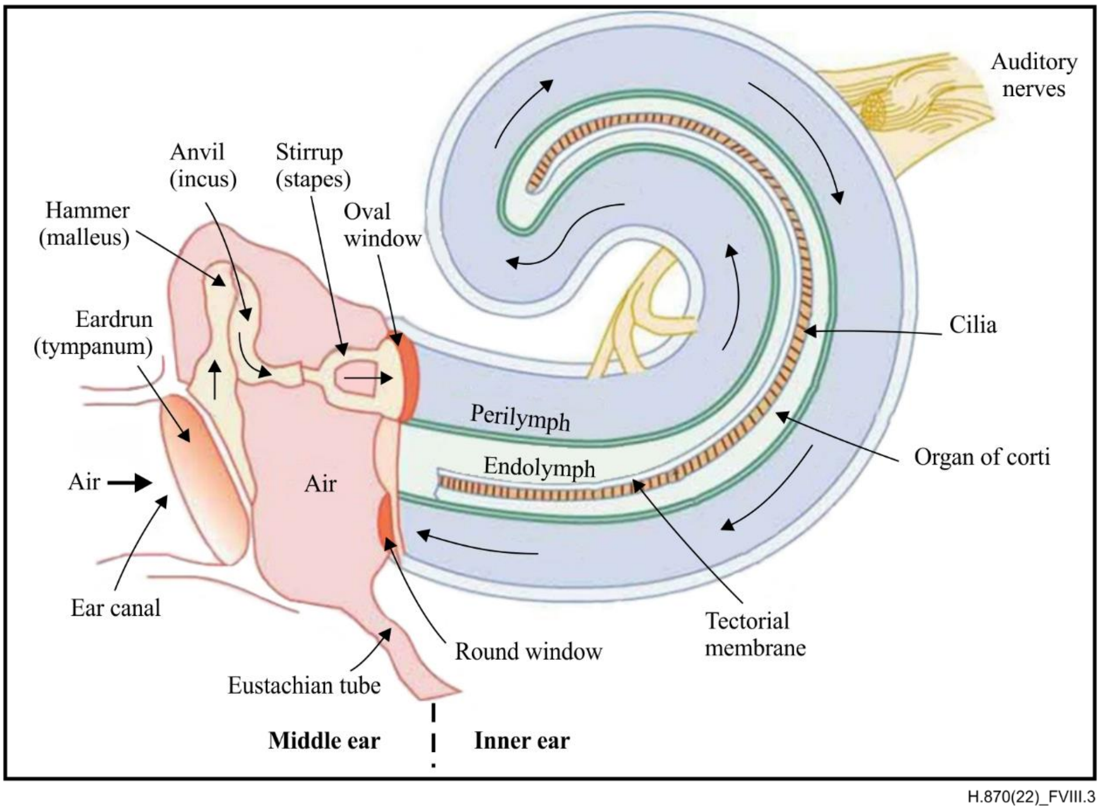


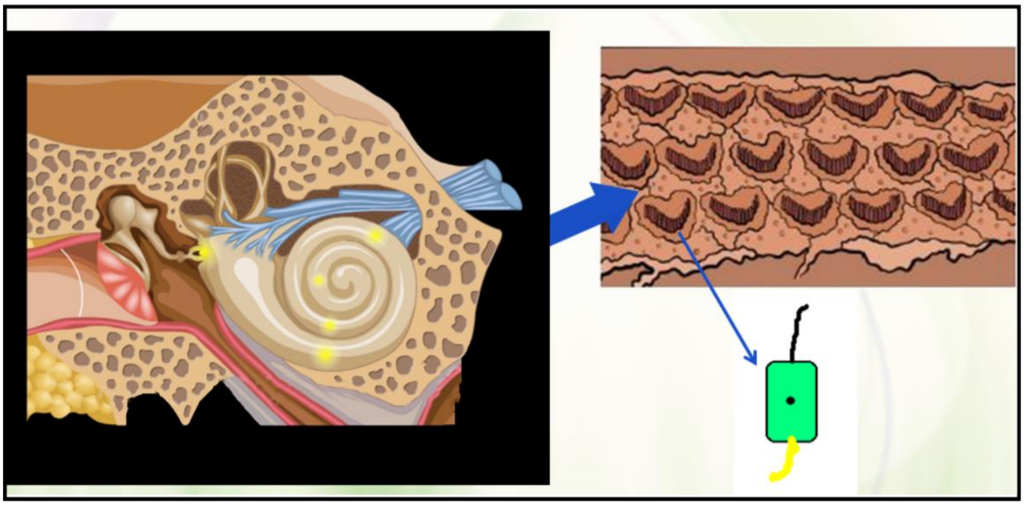
Figure VIII.3 – Illustration of the cochlea

As shown in Figure VIII.2 and Figure VIII.3, the cochlea is a snail shaped organ. In the cochlea, there are thousands of hair cells called basilar hairs. As the sound goes through the cochlea, it moves the fluid which moves the hair cells, sending electrical impulses up the auditory nerve to the brain. These electrical signals are then interpreted as sound.

When overexposure to sound occurs, the hair cells in an ear become overstimulated. Once the hair cells are overstimulated, they become fatigued and stop responding to sound. This may result in temporary threshold shift (TTS), a temporary hearing loss following sound exposure, which can last a few minutes to a few days. After a period of quiet, the hair cells will recover.

However, repeated exposure to excessive sound over time will kill these hair cells, and they lose their ability to recover. This can result in permanent threshold shift (PTS), sound-induced permanent loss of hearing sensitivity associated with irreversible cochlear hair cell damage.

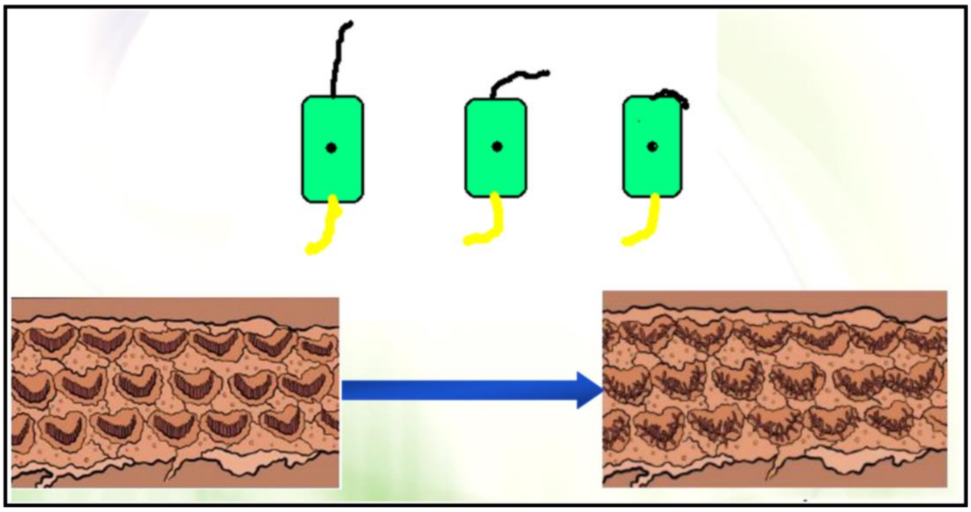
Figure VIII.4 shows the cochlea and the hair cells.



H.870(22)_FVIII.4

Figure VIII.4 – Illustration of the cochlea and the hair cells

In Figure VIII.5, the hair cells of the cochlea on the left are of a person with normal hearing, and the one on the right shows the permanent damage overexposure to sound can cause.



H.870(22)_FVIII.5

Figure VIII.5 – Illustration of sound induced damage in hair cells

VIII.3 Measurement of sound energy

VIII.3.1 Pressure

Because of earth's gravity, the weight of the atmosphere exerts a pressure in all directions on everything, called atmospheric pressure. Its value is 105 Newton/m^2; that is, 105 Pascal (Pa).

The displacement of a wave is the amount of disturbance from equilibrium produced by the wave.

Peak-to-peak refers to the change between minimum and maximum values of a sinusoidal wave or signal. Figure VIII.6 shows the concept of peak-to-peak.

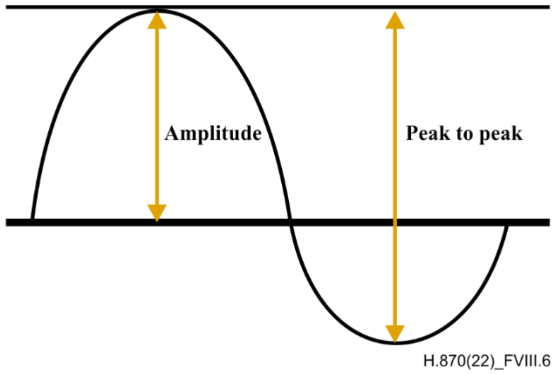


Figure VIII.6 – Concepts of signal amplitude and peak to peak value

Amplitude of a sound wave is often calculated as root mean square (RMS) values. Root mean square is the square root of the mean (average) value of the squared function of the instantaneous values. The RMS value is computed by first squaring the waveform instantaneous values (s), then finding the mean over a cycle (m) and finally by taking the square root (r).

VIII.3.2 Decibels

Editor's note: move this explanation to an Appendix

The 'bel' (symbol B) expresses the ratio of two values by the decimal logarithm of this ratio. This unit is not often used, having been replaced by the decibel (symbol dB) which is one-tenth of a bel.

A logarithmic unit used to express the ratio of two values of a physical quantity. One of these values is often a standard reference value, in which case the decibel is used to express the level relative to that reference. The mathematical statement of this idea is

$$L_2 - L_1 = Log10\left(\frac{I_2}{I_1}\right)$$

The verbal translation is that the difference in levels, measured in decibels (dB), between sounds 2 and 1 is given by the common (base 10) logarithm of the ratio of the intensities. The factor of 10 is included to expand the scale. A review of the log function makes a few features of the level (decibel) scale apparent. Because log(1) = 0, if sounds 1 and 2 have the same intensity then the difference in their levels is 0. The function of the log scale is to transform ratios into differences. If L_2 is twice L_1 then $L_2 - L_1 = 3\ dB$, no matter what the actual value of L_2, L_1 might be. That is because log(2) = 0.3 [b-Hartmann].

VIII.3.2.2 dB SPL

Although the decibel scale is a ratio scale in which a quantity is always compared with another quantity, it is common for individual sound levels to be expressed in decibels as though the measure were absolute. Sound pressure level is the logarithm, generally expressed in decibels, of the ratio of sound pressure p and a reference pressure pA0, often 20 µPa. Note that a factor of 20 is used when the ratio is between two sound pressures, rather than two sound intensities.

$$SPL = 20\left(\frac{p}{p_{0A}}\right)$$

VIII.3.2.3 dBA

dBA is decibels of sound pressure level measured using the A-weighting network; a level frequency weighting intended to measure low-intensity sound (around 40 phon loudness level) but which has become commonly used also for measuring occupational and environmental sound exposures.

Figure VIII.7 shows a conceptual view of the roles of the different corrections used in measurements, to give certain weightings to various frequencies.

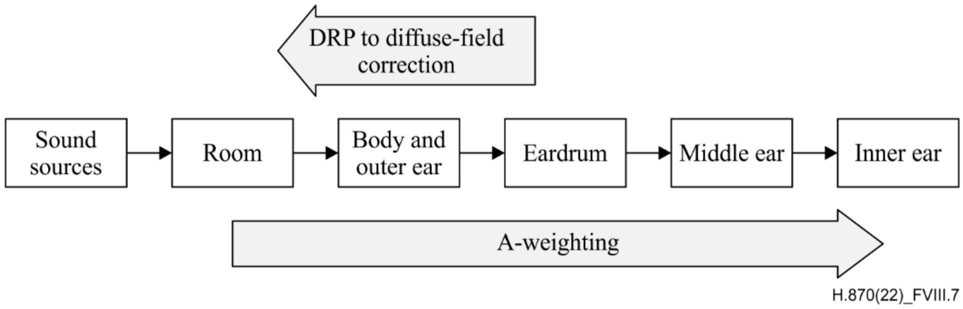


Figure VIII.7 – Conceptual view of the roles of the different corrections used in measurements, to give certain weightings to various frequencies

VIII.3.2.4 dBFS

dB full scale is the signal level of a digital signal relative to its overload or maximum level. Different conventions exist. It is common to assign a digital representation of a full-scale sinusoidal the value of 0 dBFS RMS. The peak level can then reach +3.01 dBFS. In other cases, the RMS level of a digital full-scale square wave is assigned 0 dBFS RMS. The maximum peak level is then also 0 dBFS. For the latter cases, dBFS is equivalent to dBov.

NOTE – Also known as dBov, dB relative to digital overload is the signal level of a digital signal relative to its overload or maximum level. See [ITU-T G.100.1].

VIII.3.2.5 dBHL

dBHL is decibels of hearing level at a certain frequency; a level used to measure audiometric hearing threshold relative to a defined normal.

As described in [ISO 226], the sensitivity of the human ear varies greatly depending on the frequency of the incoming sound. If, and if the volume is turned up in order to obtain enough loudness in the low-frequency range that is important for many genres of music, the ear may be exposed to excessive energy at the higher frequencies to which it is especially sensitive.

Figure VIII.8 shows acoustics normal equal-loudness-level contours.

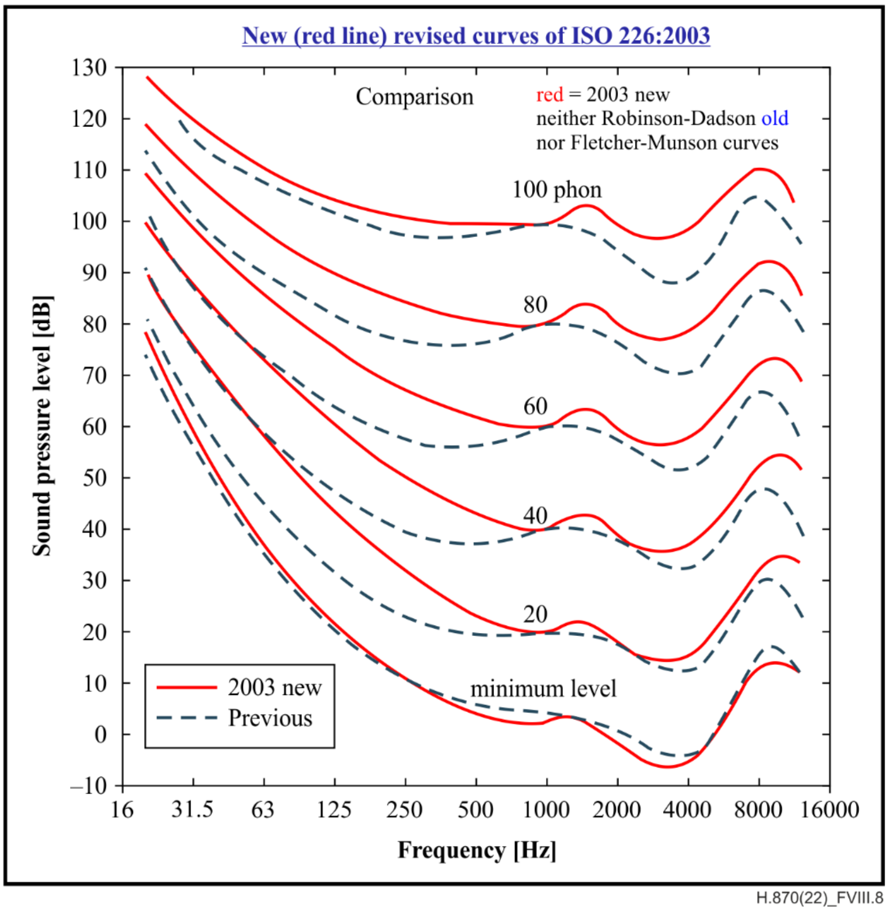


Figure VIII.8 – Acoustics normal equal-loudness-level contours

VIII.4 Equal energy principle

The equal energy principle is the premise that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time.

According to this principle, equal amounts of sound energy are expected to cause equal amounts of sound-induced permanent threshold shift regardless of the distribution of the energy over time.

Based on this principle, a 'dose' of sound energy may be defined as the squared A-weighted sound pressure, P_A, integrated over the exposure time $T = t_2 - t_1$.

Mathematically, this is expressed as:

$$dose = \int_{t1}^{t2} (P_A(t))^2) dt$$

where P_A is the A-weighted and diffuse-field corrected sound pressure.

The unit of this value is Pascal squared hours, or Pa^2h.

Bibliography

[b-ITU-T P.10] Recommendation ITU-T P.10/G.100 (2017), *Vocabulary for performance and quality of service*.

[b-ITU-T P.360] Recommendation ITU-T P.360 (2006), *Efficiency of devices for preventing the occurrence of excessive acoustic pressure by telephone receivers and assessment of daily noise exposure of telephone users*.

[b-ITU-T T.180] Recommendation ITU-T T.180 (1998), *Homogeneous access mechanism to communication services*.

[b-ITU-R V.574] Recommendation ITU-R V.574 (2015), *Use of the decibel and the neper in telecommunications*.

[b-Berger] Berger, E.H. and Royster, L.H. (1996), *In search of meaningful measures of hearing protector effectiveness.*

[b-Berger-Voix] Elliott H. Berger and Jérémie Voix (2018), *Hearing Protection Devices,* in *The Noise Manual*, 6th Edition, American Industrial Hygiene Association.

[b-Blanco-Wetherill] A. Blanco and J. Wetherill (April 2019), Headphones Market Report Worldwide Outlook, Futuresource Consulting Ltd. https://www.futuresource-consulting.com/reports/posts/2019/april/futuresource-headphones-market-report-worldwide-apr-19/, pg. 11 & 22.

[b-Borg] Erik Borg, Roland Nilsson, Gunnar Lidén. (1979), *Fatigue and recovery of the human acoustic stapedius reflex in industrial noise*, The Journal of the Acoustical Society of America Vol. 65, 846.

[b-Brask] Torben Brask (1978), *The Noise Protection Effect of the Stapedius Reflex*, Acta Oto-Laryngologica Vol. 86, – Issue sup360.

[b-Brask-2009] Torben Brask (2009), *The Noise Protection Effect of the Stapedius Reflex*, Acta Oto-Laryngologica Vol. 86, 1978 – Issue sup360.

[b-Burns-1973] William Burns (1973), Noise and Man, J.B. Lippincott Company, ISBN 9780397580989, pp. 243-247.

[b-Burns-Robinson] W. Burns and D.W. Robinson, (1970) Hearing and Noise in Industry, Her Majesty's Stationery Office, pp. 142-145. This full document can be found here: https://archive.org/details/op1268848-1001/page/n153

[b-EN 71-1] CEN EN 71-1:2014, *Safety of toys – Part 1: Mechanical and physical properties*.

[b-2009/490/EC] European Commission, *Commission Decision of 23 June 2009 on the safety requirements to be met by European standards for personal music players pursuant to Directive 2001/95/EC of the European Parliament and of the Council* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009D0490

[b-Fligor] Brian J. Fligor, and Terri Ives. "Does Earphone Type Affect Risk for Recreational Noise-Induced Hearing Loss?" in *2006 Noise Induced Hearing Loss (NIHL) Children's Conference Proceedings.*

[b-FSTP-SLD-UC] ITU Technical Paper (2022), *Gap analysis: Use cases of safe listening devices*. https://www.itu.int/pub/T-TUT-EHT-2022 [b-Hammershøi] Hammershøi, D., & Møller, H. (2008), *Determination of noise immission from sound sources close to the ears*. Acustica United with Acta Acustica, 94 (1).

[b-Hansen] C. Hansen (2006), *Occupational exposure to noise: evaluation, prevention and control – chapter 1 Fundamentals of acoustics*. http://www.who.int/occupational_health/publications/occupnoise/en/

[b-Hartmann] William M. Hartmann. *Physical Description of Signals* in [b-Moore].

[b-Loy] Gareth Loy, *Musimathics.* MIT (2011)

[b-Moller 1995] Henrik Möller (1995), *Transfer characteristics of headphones measured on human ears*, J. Audio Eng. Soc:43, pp. 203-217.

[b-Moller 2013] Aage R. Moller, (2013) *Hearing*, 3rd ed. Plural Publishing.

[b-Moore] Brian C.J. Moore (ed.) (1995) *Hearing.* Academic Press.

[b-Neitzel and Fligor] R. Neitzel and B. Fligor (2019), *Risk of noise-induced hearing loss due to recreational sound: Review and recommendations*. The Journal of the Acoustical Society of America 146, 3911; https://doi.org/10.1121/1.5132287

[b-NIOSH] National Institute for Occupational Safety and Health. (1998). *Criteria for a recommended standard: Occupational noise exposure, revised criteria*. Pub. No. 98-126.

[b-Nixon-Glorig, 1961] J.C. Nixon and A. Gorig (1961), *Noise-Induced Permanent Threshold Shift at 2000 cps and 4000 cps*, The Journal of the Acoustical Society of America, Vol.33, Issue 7, 904. http://dx.doi.org/10.1121/1.1908841

[b-Portnuff] Portnuff C.D., Fligor B.J., Arehart K.H. (2011), *Teenage use of portable listening devices: a hazard to hearing?* Journal of the American Academy of Audiology. Nov-Dec; 22(10):663-77.

[b-Price 1981] Price, G. R. (1981), *Implications of a Critical Level in the Ear for Assessment of Noise Hazard at High Intensities*, J. Acoust. Soc. Am. 69, 171-177.

[b-SCENIHR] Scientific Committee on Emerging and Newly Identified Health Risks (2008), *Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function.* European Commission.

[b-SG16-R17] ITU-T Study Group 16, *Report of the fourth meeting of Study Group 16* (Geneva, 19-29 March 2019) – Working Party 2/16 (Multimedia e-services). https://www.itu.int/md/T17-SG16-R-0017/en

[b-Silman] Shlomo Silman. (1984), *The Acoustic Reflex: Basic Principles and Clinical Applications*, Academic Press.

[b-Smith-Voix] Jérémie Voix, Pegeen Smith, and Elliott H. Berger (2018), *Field Fit-Testing and Attenuation Measurement Procedures,* The Noise Manual, 6th Edition, American Industrial Hygiene Association.

[b-SMR] Kei J. (2012), *Acoustic stapedial reflexes in healthy neonates–normative data and test-retest reliability.* J Am Acad Audiol. 23(1):46-56.

[b-Vér] I. Vér, L. Beranek (2006), *Noise and Vibration Control Engineering*.

[b-Voix,Cocq,Hager] J. Voix, C. Le Cocq, and L. D. Hager (2008), *The Healthy Benefits of Isolating Earphones*, in Proceedings of Meetings on Acoustics, vol. 4, p. 050003.

[b-WHO 2018] World Health Organization, *Deafness and hearing loss*, https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss (visited 2022-06-01)

[b-Zakrisson] John-Erik Zakrisson & Erik Borg. (1974), *Stapedius Reflex and Auditory Fatigue*, Journal of Audiology, Vol. 13, pp. 231-35.

[b-Zakrisson] John-Erik Zakrisson. (1979), *The effect of the stapedius reflex on attenuation and poststimulatory auditory fatigue at different frequencies*. Acta Otolaryngol Suppl. 360:118-21.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	**Audiovisual and multimedia systems**
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2022