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Speech and multimedia Transmission Quality (STQ);
Transmission quality and speech intelligibility
for hearing impaired people

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Speech and multimedia Transmission Quality (STQ).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

The present document provides data and information on studies that have shown that hearing impaired people are suffering of insufficient intelligibility of transmitted speech, due to background noises, transmission impairments, shapes of receivers, tandeming of speech processing and coupling between earphones and hearing aids.

It also shows that wideband bandwidth provides improved quality than achieved with narrowband for hearing impaired people using hearing aids, cochlear implants.

The present document is intended as a first step of a potential work plan which needs to be constructed in order to define scenarios to conduct subjective tests on intelligibility, listening effort and quality for hearing impaired people with different hearing profiles, and to define and validate an objective model to predict speech intelligibility, listening effort and quality for hearing impaired people, both by using hearing aids or not. The next phase should consist, at least, to study:

- how the listening quality for hearing impaired people can be improved, with or without hearing devices (including loudness, spectrum equalization or enhancement, etc.);
- how to determine the impact of the different transmission impairments on intelligibility for different types of hearing profiles, such as the potential impact of coupling between phone receivers and hearing aids (e.g. acoustical, inductive coupling);
- which kind of model(s) can best assess objectively the intelligibility of natural and synthesized speech;

- what kind of model could determine the listening effort needed to follow and understand a conversation.

The impairments from the distant send side may also have impacts on intelligibility of received speech, hence might need performance improvements.

Introduction

Several studies have shown that hearing impaired people suffer from less sufficient intelligibility of transmitted speech, due to background noises, transmission impairments, types of receivers, low quality coupling between earphones and hearing aids. It was also noted that an important parameter to be assessed is the listening effort.

There is also a lack of subjective tests on intelligibility for hearing impaired people and there is no standardized objective model to predict speech intelligibility as perceived by hearing impaired people. Such tests should be done, at least, in wideband, as very few results are available for this bandwidth and it has been shown that wideband speech provides improvements compared to narrowband speech for hearing impaired people.

The present document is a first step to improve and assess the intelligibility of transmitted speech for hearing impaired people.

It is expected that new documents, specifications or standards could be produced for specific applications, e.g. to associate text to speech in order to improve the intelligibility for the users, and to consider the best way to define relevant standards for these combinations.

For further works, at least four topics have been identified. The three first topics could be developed by the ETSI TC STQ and the fourth topic by the ETSI TC HF (Human Factors):

- Receive side for hearing impaired people, with or without hearing aids (including loudness, equalization, etc.), including modeling the listening effort.
- Impact of the different transmission impairments on intelligibility, quality and listening effort.
- Impairments from the send side and consequences on intelligibility - improvements are expected.
- Association of text and speech, and consequences for intelligibility.

Acoustical, inductive, wireless and electrical couplings between phones and hearing aids should be taken into account, as well as the different types of hearing aids (e.g. cochlear implants).

1 Scope

The present document provides a review of existing test methodologies to assess speech intelligibility, quality and listening effort.

It should be noted that most test methods (for quality or intelligibility) have been developed with normal hearing people and that there is a lack of data for hearing impaired people.

Some clauses of the present document provide a review of existing methods or test results that take into account couplings between phones and listener's ears (acoustical coupling), and coupling between phones and hearing aids (inductive, acoustical or via radio links). Different hearing impairments affecting the listening performance are also considered.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEC 60118 series: "Hearing aids".

[i.2] Recommendation ITU-T P.10/G.100: "Vocabulary for performance and quality of service".

[i.3] Recommendation ITU-T P.16: "Subjective effects of direct crosstalk; thresholds of audibility and intelligibility".

[i.4] Recommendation ITU-T P.85: "A method for subjective performance assessment of the quality of speech voice output devices".

[i.5] ETSI EN 301 549: "Accessibility requirements suitable for public procurement of ICT products and services in Europe".

[i.6] Recommendation ITU-T P.807: "Subjective test methodology for assessing speech intelligibility".

[i.7] Recommendation ITU-T P.1311: "Method for determining the intelligibility of multiple concurrent talkers".

[i.8] ETSI ES 200 381-1 (V1.2.1) (10-2012): "Telephony for hearing impaired people; Inductive coupling of telephone earphones to hearing aids; Part 1: Fixed-line speech terminals".

[i.9] ETSI ES 200 381-2 (V1.1.1) (10-2012): "Telephony for hearing impaired people; Inductive coupling of telephone earphones to hearing aids; Part 2: Cellular speech terminals".

[i.10] ETSI ETS 300 488 ed.1 (01-1996): "Terminal Equipment (TE); Telephony for hearing impaired people; Characteristics of telephone sets that provide additional receiving amplification for the benefit of the hearing impaired".

[i.11] ETSI TR 102 949: "Speech and multimedia Transmission Quality (STQ); Wideband and Superwideband speech terminals; Perceptually motivated parameters".

[i.12] ANSI/ASA S3.2-2009 (R2014): "Method For Measuring The Intelligibility Of Speech Over Communication Systems".

[i.13] Recommendation ITU-T P.862: "Perceptual evaluation of speech quality (PESQ): An objective method for end-to-end speech quality assessment of narrow-band telephone networks and speech codecs".

[i.14] Recommendation ITU-T P.863: "Perceptual objective listening quality assessment".

[i.15] ETSI ES 202 396-1: "Speech and multimedia Transmission Quality (STQ); Speech quality performance in the presence of background noise; Part 1: Background noise simulation technique and background noise database".

[i.16] ETSI EG 202 396-2: "Speech Processing, Transmission and Quality Aspects (STQ); Speech quality performance in the presence of background noise; Part 2: Background noise transmission - Network simulation - Subjective test database and results".

[i.17] ETSI EG 202 396-3: "Speech and multimedia Transmission Quality (STQ); Speech Quality performance in the presence of background noise; Part 3: Background noise transmission - Objective test methods".

[i.18] Ute Jekosch, Technische Universität Dresden: "Test on overall quality as perceived by high frequency hearing impaired subscribers", ITU-T SG12 - C101 - September 2007.

[i.19] John Beerends, Ronald Van Buuren, Jeroen Van Vugt, Jan Verhave: "Objective Speech Intelligibility Measurement on the basis of natural speech in combination with perceptual modeling", JAES, Vol.57, N 5, May 2009.

[i.20] Hearcom project (hearcom.eu).

[i.21] Directive 93/42/EEC of 14 June 1993 concerning medical devices.

[i.22] Report on 2012 HLAA Convention. NB versus WB Speech Study.

[i.23] ITU-T Contribution SG12 - C93 - November 2013: "Subjective and objective measurement of synthesized speech intelligibility in modern telephone conditions".

[i.24] Sridhar Kalluri, Starkey Hearing Research Center (Berkeley): "High frequency sound for the hearing impaired".

NOTE: Available at https://www.itu.int/dms_pub/itu-t/oth/06/17/T061700000D0011PDFE.pdf.

[i.25] Linda Kozma-Spytek. Technology Access Program. Gallaudet University; Washington, DC: "Voice Telecommunications Accessibility for Individuals with Hearing Loss".

NOTE: Available at STQ(14)47_038_Voice_Telecommunications_Accessibility_for_Individuals_with_.zip.

[i.26] Hearing4all.

NOTE: Available at http://hearing4all.eu/EN/.

[i.27] ISO TR 22411: "Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities".

[i.28] ISO/IEC Guide 71: "Guide for addressing accessibility in standards".

[i.29] ANSI/ASA S3.5-1997 (R2012): "American National Standard Methods for Calculation of the Speech Intelligibility Index".

[i.30] ANSI S3.2-1989 (R1999): "Method For Measuring The Intelligibility Of Speech Over Communication Systems".

[i.31] ETSI TS 103 558: "Speech and multimedia Transmission Quality (STQ); Methods for objective assessment of listening effort".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

articulation index: A measure of the intelligibility of voice signals, expressed as a percentage of speech units that are understood by the listener when heard out of context. The articulation index is based on partially empirical, partially theoretical principles to predict the speech intelligibility under known signal-to-noise conditions. Please see Recommendation ITU-T P.10/G.100 [i.2] ("*Definition generally used in psychoacoustics*").

articulation scale: Opinion scale for measuring the impression of clarity felt by a listener. How distinguishable are the words composing the message? (from Recommendation ITU-T P.85 [i.4]).

hearing aids: medical devices in the context of Directive 93/42/EEC (MDD) [i.21] comprising electro acoustic amplifiers including a microphone and a loudspeaker and having a frequency response and dynamic characteristics specific to each person's individual hearing loss

real-time text: form of a text conversation in point to point situations or in multipoint conferencing where the text being entered is sent in such a way that the communication is perceived by the user as being continuous (from ETSI EN 301 549 [i.5])

speech intelligibility: measure of how comprehensible speech is in given conditions

NOTE: Intelligibility is affected by the quality of the speech signal, the type and level of background noise, reverberation, and, for speech over communication devices, the properties of the communication system.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CVC	Consonant Vowel Consonant
HF	Human Factors
HLAA	Hearing Loss Association of America
ICT	Information and Communication Technologies
NB	Narrowband
PESQ	Perceptual Evaluation of Speech Quality

NOTE: Refers to Recommendation ITU-T P.862 [i.13].

POLQA	Perceptual Objective Listening Quality Assessment

NOTE: Refers to Recommendation ITU-T P.863 [i.14].

RLR	Receiving Loudness Rating
RTT	Real Time Text
SII	Speech Intelligibility Index
STI	Speech Transmission Index
TC	Technical Comittee
WB	Wideband

4 Coupling between hearing aids and phones

4.1 ETSI Standards on coupling of phones with Hearing aids

At least the following standards define the performance that should be fulfilled when coupling phones with hearing aids:

- Inductive coupling: both ETSI ES 200 381-1 [i.8] and ETSI ES 200 381-2 [i.9] define the requirements and test measurements for the phones intended to be coupled via inductive transmission with hearing aids. ETSI EN 301 549 [i.5] refers also to these two ESs.
- Acoustical coupling ETSI ETS 300 488 [i.10]: This ETS specifies the electro-acoustic performance characteristics of telephony terminals which are intended for direct application to the ear and which provide, at the earphone, additional amplification in the receiving direction compared with the Receiving Loudness Rating (RLR) specified in the relevant terminal standard.
- ETSI TC STQ is currently working on a work Item: "Telephony for hearing impaired people; Characteristics of wireless and VoIP speech terminals that provide additional receiving amplification for the benefit of the hearing impaired".
- The hearing aids performance are standardized in a series of standards referenced as IEC 60118 [i.1].

It should be taken into account that this ETS does not apply to wireless or VoIP speech terminals, does not take into account handsfree speech terminals and applies only to narrowband speech.

In addition to requirements on "magnetic coupling" (defined as "inductive coupling" in the ETSI ES 200 381-1 [i.8] and ETSI ES 200 381-2 [i.9]), ETSI EN 301 549 [i.5] defines requirements for speech volume gain as follows:

- *"Speech volume range: Where ICT hardware has speech output, it shall provide a means to adjust the speech output volume level over a range of at least 18 dB".*
- *"Incremental volume control: Where ICT hardware has speech output and its volume control is incremental, it shall provide at least one intermediate step of 12 dB gain above the lowest volume setting".*

4.2 Impact of wideband on speech understanding

Report on 2012 HLAA Convention NB versus WB Speech Study [i.22].

"Summary: Testing of narrowband versus wideband telephone speech was completed at the 2012 HLAA convention with a group of 22 cochlear implantees. Results showed access to wideband telephone audio improved speech understanding (in quiet) over speech understanding using typical narrowband telephone audio. In addition, an advantage was found for wideband audio among participants in terms of lowering the ***mental effort*** *expended during completion of the speech understanding task compared to that expended during task completion for narrow band audio testing."*

5 Subjective tests

5.1 Introduction

Recommendation ITU-T P.16 (11/1988) - Subjective effects of direct crosstalk; thresholds of audibility and intelligibility) [i.3] and Recommendation ITU-T P.85 (06/1994) -A method for subjective performance assessment of the quality of speech voice output devices) [i.4] may be considered as initial materials, but are no more sufficient for the modern devices and networks.

Recently, ITU-T Study Group 12 has developed the new Recommendation ITU-T P.807 [i.6]. However, the Recommendation has been validated only with normal hearing people.

In order to define an objective model able to compute the intelligibility, as perceived by normal and hearing impaired people, there is a need to define the most relevant subjective tests and test plans.

NOTE: ITU-T also published another Recommendation for assessing speech intelligibility. However Recommendation ITU-T P.1311 [i.7] is mainly for the intelligibility of multiple concurrent talkers. This Recommendation also refers to an ANSI Standard: To evaluate the intelligibility of a single talker over a communication system practitioners are referred to the recent version (R2014) of ANSI/ASA S3.2-2009 "Method For Measuring The Intelligibility Of Speech Over Communication Systems" [i.12].

5.2 Subjective test methodology for assessing speech intelligibility

Recommendation ITU-T P.807 [i.6] describes a subjective testing methodology for assessing speech intelligibility in communications settings, systems and devices. The method provides a percent correct intelligibility score based on a two-alternative forced-choice task, where the stimulus is one of the two words from a pair of words, i.e. a test item. Half of the test items consist in rhyming word-pairs (i.e. they differ only in the initial consonant) and half are alliterative word-pairs (i.e. they differ only in the final consonant). The two critical consonants in each test item differ only in a single distinctive feature. In addition to a score for overall intelligibility, the method provides scores for each of six distinctive features: voicing, nasality, sustention, sibilation, graveness and compactness. These scores may be used to diagnose the specific cause of impairments leading to degradation of speech intelligibility.

5.3 Summary of existing studies

5.3.1 References of studies and projects

Some studies or projects have already provided some useful elements for the topic:

Ute Jekosch, Technische Universität Dresden [i.18**]:** Test on overall quality as perceived by high frequency hearing impaired subscribers.

ITU-T SG12 - C101 - September 2007 [i.18**]: Listening** tests in Narrowband speech only, but some investigations about equalization, level adjustment and impact of coders and packet loss.

Sridhar Kalluri, Starkey Hearing Research Center (Berkeley) [i.24]**:** The study has shown that hearing impaired people have shown the benefit of expanding the bandwidth from 4 kHz to 6 kHz (an important bandwidth for speech intelligibility), (interest for wideband transmission).

Hearcom project [i.20**]** has conducted several subjective tests with hearing impaired people (with or without hearing aids) and has made some investigations on quality modeling (in Narrow-band) and on intelligibility models (but mainly in different acoustical situations). Very little impact of the results on standards.

Some parameters such as intelligibility or clarity need to be more investigated. The "on line questionnaire" available on Hearcom.eu points in particular of the influence of the environmental noise and on the capability for people to understand the speech contents.

ITU-T Contribution SG12 - C93 - November 2013 [i.23**]:** "Subjective and objective measurement of synthesized speech intelligibility in modern telephone conditions". The study is based on two models called in the contribution as "POLQA intelligibility" and "POLQA intelligibility".

A new **ETSI STQ study (ETSI TS 103 558 [**i.31**]):** Methods for objective assessment of listening effort. This work is intended to develop methods for the objective prediction of listening effort (and eventually listening quality) at the near-end side in the presence of background noise. The work will be based on the results of subjective studies.

5.3.2 Summary of the study Voice telecommunications accessibility for individuals with hearing loss

A related research "Voice Telecommunications Accessibility for Individuals with Hearing Loss" [i.25] has been carried out with the aim to better understand the technical parameters that lead to effective audio-only and audio/visual telecommunications by individuals with hearing loss.

The conclusions of the study may be summarized as:

- The addition of video significantly enhanced speech understanding in telephony applications for individuals with hearing loss (see experiments 1 to 4).
- Wide-band (WB) audio enhanced speech understanding compared with Narrow-band (NB) audio (see experiments 3 to 5).
- Frame rate and audio-video synchrony have large effects on speech understanding for videotelephony. The following values are recommended:
  - Frame rate: 15 f/s as a minimum
  - Audio-Video synchrony: 0 ms - +100 ms audio re video are preferred.

6 Models for intelligibility assessment

6.1 Summary of existing studies

Some studies or projects have already provided some useful elements for the topic:

ETSI ES 202 396-1 [i.15**], ETSI EG 202 396-2 [**i.16**] and ETSI EG 202 396-3 [**i.17**]** define methodologies and model to qualify the quality of speech in noisy environments (and global quality). The model is defined for wideband but the subjective tests were conducted only with normal hearing people (who are not so sensitive to noise than hearing impaired people).

ISO TR 22411 [i.27] (Ergonomics data and guidelines for the application of ISO/IEC Guide 71 [i.28] to products and services to address the needs of older persons and persons with disabilities) provide sets of curves defining the hearing loss/age, and refers to STI for intelligibility testing (STI is well known for room acoustics but not applicable to telecommunication situations).

ANSI/ASA S3.5-1997 (R2012) American National Standard Methods for Calculation of the Speech Intelligibility Index [i.29].

This standard defines a method for computing a physical measure that is highly correlated with the intelligibility of speech as evaluated by speech perception tests given a group of talkers and listeners. The measure is called the Speech Intelligibility Index, or SII. The SII is calculated from acoustical measurements of speech and noise. This standard is not a substitute for ANSI S3.2-1989 (R1999) American National Standard Method for Measuring the Intelligibility of Speech over Communications Systems [i.30].

Recommendation ITU-T P.863 [i.14**]** defines a model (POLQA) which is intended to take into account the acoustical parts of the speech transmission. It is working in Superwideband. As usually based on normal hearing (mainly young) people. Adaptations should be needed in particular for acoustical ends. Studies have provided results on intelligibility for natural and synthesized speech from models based on Recommendations ITU-T P.862 [i.13] and P.863 [i.14].

Objective Speech Intelligibility Measurement on the basis of natural speech in combination with perceptual modeling [i.19**]:** The aim of this study is to look for the relation between subjective and objective speech intelligibility measurements. For a large series of speech degradations, noise, linear and nonlinear distortions (speech codecs), intelligibility tests were carried out using short CVC words.

In the objective domain Recommendation ITU-T P.862 [i.13] is used as the starting point to develop a perceptual model that allows predicting the perceived intelligibility of a speech fragment.

ITU-T Contribution SG12 - C93 - November 2013 [i.23**]:** "Subjective and objective measurement of synthesized speech intelligibility in modern telephone conditions". The study is based on two models called in the contribution as "POLQA intelligibility" and "POLQA intelligibility".

Additionally, **Hearing4all [**i.26**]** is an initiative to define "Models, technology and solutions for diagnostics, restoration and support of hearing".

6.2 Need for a new model

The review of the existing publications, test methodologies and objective model shows that there is a need to define and validate a new model. Hence studies are necessary to achieve this objective.

When such desirable new model will be developed, some data available in ETSI TR 102 949 [i.11] could be taken into account.

7 Potential benefits of RTT for intelligibility

7.1 Introduction

Real Time Text (RTT) is defined in several standards or Recommendations, as indicated in the following clauses.

7.2 Real Time Text performance

Clause 6.2 of ETSI EN 301 549 [i.5] defines:

- RTT provision (RTT communication and concurrent voice and text).
- Display of Real-time Text (visually distinguishable display and programmatically determinable send and receive direction).
- Interoperability.
- Real-time text responsiveness.

7.3 Combination of speech communications and RTT

In the clause "concurrent voice and text" of ETSI EN 301 549 [i.5] it is stated:

"Where ICT supports two-way voice communication in a specified context of use, and enables a user to communicate with another user by RTT, it shall provide a mechanism to select a mode of operation which allows concurrent voice and text.

NOTE: The availability of voice and RTT running concurrently can allow the RTT to replace or support voice and transfer additional information such as numbers, currency amounts and spelling of names."

Annex A: Bibliography

Søren Jørgensen and Torsten Dau Predicting speech intelligibility based on the signal-to-noise envelope power ratio after modulation-frequency selective processing. J. Acoust. Soc. Am. Volume 130, Issue 3, pp. 1475-1487 (2011); (13 pages).

Jianfen Ma, Yi Hu and Philipos C. Loizou. Objective measures for predicting speech intelligibility in noisy conditions based on new band-importance functions. J Acoust Soc Am. 2009 May; 125(5): 3387-3405.

Status of Speech intelligibility studies and models for hearing impaired people. Plans for standardizations. Jean-Yves Monfort, JYMC.I.S.
http://docbox.etsi.org/Workshop/2014/201406_HFWORKSHOP/S02_Speech_Intelligibility/S02_Monfort_JYMLCIS.pdf.

Predicting speech intelligibility based on the signal-to-noise envelope power ratio after modulation-frequency selective processing. Ewert and Dau [(2000). J. Acoust. Soc. Am. **108**, 1181-1196].

Subjective and objective measurement of synthesized speech intelligibility in mobile networks. Peter Pocta, University of Zilina, Slovakia
http://docbox.etsi.org/Workshop/2014/201406_HFWORKSHOP/S02_Speech_Intelligibility/S02_Pocta_Uniza.pdf.

Amélioration de l'intelligibilité de signaux vocaux automobiles par traitements adaptés aux capacities auditives. V. Roussarie, M. Daniel, L. Vauchier, D. Jacquet, JF Sciabica. Paper presented at CFA 2014, Poitiers (France)
This document is an introduction to an ANR project (AIDA, started in January 2014, in France).

Speech Intelligibility and Quality of transmitted speech under packet loss. F. Schiffner, J.Skowronek, A. Raake. Forum Acusticum, September 7-12 2014, Krakow, Poland. (An updated version of the paper will be submitted to ITU-T Study Group 12).
The study focuses on the speech intelligibility of packet loss in VoIP and compares the results with the speech intelligibility in noisy conditions. It also investigates the relation between speech intelligibility and quality ratings of transmitted speech, for both packet loss and noise conditions.

Subjective and objective measurement of synthesized speech intelligibility in modern telephone conditions. Peter Pocta, John G. Beerends, a Dept. of Telecommunications and Multimedia, FEE, University of Zilina, SK-01026 Zilina, Slovakia. Available online since 9 April 2015, at www.sciencedirect.com (Speech Communication 71 (2015) 1-9).

Subjective and Objective Measurement of the Intelligibility of Synthesized Speech Impaired by the Very Low Bit Rate Stanag 4591 Codec Including Packet Loss. Peter Pocta1, John G. Beerends2. Acta Acustica United with Acustica. Vol. 103 (2017) 311-316.

History

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