

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.107.1

(06/2019)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

International telephone connections and circuits –
Transmission planning and the E-model

Wideband E-model

Recommendation ITU-T G.107.1

ITU-T



ITU-T G-SERIES RECOMMENDATIONS
TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
Transmission planning and the E-model	G.100–G.109
General Recommendations on the transmission quality for an entire international telephone connection	G.110–G.119
General characteristics of national systems forming part of international connections	G.120–G.129
General characteristics of the 4-wire chain formed by the international circuits and national extension circuits	G.130–G.139
General characteristics of the 4-wire chain of international circuits; international transit	G.140–G.149
General characteristics of international telephone circuits and national extension circuits	G.150–G.159
Apparatus associated with long-distance telephone circuits	G.160–G.169
Transmission plan aspects of special circuits and connections using the international telephone connection network	G.170–G.179
Protection and restoration of transmission systems	G.180–G.189
Software tools for transmission systems	G.190–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

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

Recommendation ITU-T G.107.1

Wideband E-model

Summary

Recommendation ITU-T G.107.1 gives the algorithm for the wideband (WB) version of the E-model as the common ITU-T transmission rating model for planning speech services that provide WB speech transmission (50-7000 Hz). This computational model can be useful to transmission planners, to help ensure that users will be satisfied with end-to-end transmission performance. The primary output of the model is a scalar rating of transmission quality. A major feature of this model is the use of transmission impairment factors that reflect the effects of different types of degradations occurring on the entire transmission path, mouth-to-ear.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.107.1	2011-12-14	12	11.1002/1000/11453
2.0	ITU-T G.107.1	2015-06-29	12	11.1002/1000/12506
3.0	ITU-T G.107.1	2019-06-29	12	11.1002/1000/13925

Keywords

E-model, speech quality, transmission planning, wideband.

* 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, 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 TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2019

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

		Page
1	Scope.....	1
2	References.....	1
3	Definitions	2
	3.1 Terms defined elsewhere	2
	3.2 Terms defined in this Recommendation.....	2
4	Abbreviations and acronyms	2
5	Conventions	3
6	WB E-model	3
	6.1 Introduction	3
	6.2 Transmission rating scale of the WB E-model.....	3
7	The structure and basic algorithms of the WB E-model.....	5
	7.1 Calculation of the transmission rating factor, R	6
	7.2 Basic signal-to-noise ratio, $R_{o,WB}$	6
	7.3 Simultaneous impairment factor, $I_{s,WB}$	6
	7.4 Delay impairment factor, $I_{d,WB}$	6
	7.5 Equipment impairment factor, $I_{e,WB}$	7
	7.6 Advantage factor, A	8
	7.7 Default values	8
	Annex A – MOS values derived from the transmission rating factor R	9
	Bibliography.....	10

Recommendation ITU-T G.107.1

Wideband E-model

1 Scope

This Recommendation describes the wideband (WB) version of a computational model, known as the E-model, that has proven useful as a transmission planning tool for assessing the combined effects of variations in several transmission parameters that affect conversational¹ quality. This computational model can be used, for example, by transmission planners to help ensure that users will be satisfied with end-to-end transmission performance whilst avoiding over-engineering of networks. It must be emphasized that the primary output from the model is the "rating factor" R , but this can be transformed to give estimates of customer opinion. Such estimates are only made for transmission planning purposes and not for actual customer opinion prediction (for which there is no agreed-upon model recommended by the ITU-T).

This version is an adapted version of the NB (300-3400 Hz) E-model, typically referred to as "the E-model", which is described in [ITU-T G.107]. The WB version addresses scenarios which include WB (50-7000 Hz) transmission. It does not replace the narrowband (NB) E-model. Instead, it describes a separate WB-version of the model that uses, within limits, similar concepts and input parameters as the NB E-model. The current version captures the effects of talker echo, absolute delay, WB speech coding, and voice-over-IP packet-loss. Degradations which are covered but have not yet been studied in detail are listener echo. Degradations which are not yet covered are loudness loss, non-optimum sidetone levels, background noise at the sending and receiving side, circuit noise and quantizing distortions.

For many parameter combinations of high importance to transmission planners, ITU-T G.107.1 can be used with confidence (e.g., loudness loss, coding distortions), but for some parameter combinations of high importance (e.g., the effects of delay in conjunction with other impairments), WB E-model predictions have been questioned and are currently under study.

Regarding the interpretation of the WB E-model ratings, note that the current versions of [b-ITU-T G.108], [b-ITU-T G.108.1] and [b-ITU-T G.109] do not refer to the WB version described here, but only to the NB version of the E-model described in [ITU-T G.107].

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.107] Recommendation ITU-T G.107 (2015), *The E-model: a computational model for use in transmission planning*.
<<http://www.itu.int/rec/T-REC-G.107>>

¹ Conversational quality in this context refers to transmission characteristics, e.g., long transmission times, effects of talker echoes, etc. However, the E-model, as described in this Recommendation, is not intended to model transmission impairments during double talk situations.

- [ITU-T G.113] Recommendation ITU-T G.113 (2007), *Transmission impairments due to speech processing*.
<<http://www.itu.int/rec/T-REC-G.113>>
- [ITU-T G.722] Recommendation ITU-T G.722 (2012), *7 kHz audio-coding within 64 kbit/s*.
<<http://www.itu.int/rec/T-REC-G.722>>
- [ITU-T O.41] Recommendation ITU-T O.41 (1994), *Psophometer for use on telephone-type circuits*.
<<http://www.itu.int/rec/T-REC-O.41>>
- [ITU-T P.800] Recommendation ITU-T P.800 (1996), *Methods for subjective determination of transmission quality*.
<<http://www.itu.int/rec/T-REC-P.800>>
- [ITU-T P.833] Recommendation ITU-T P.833 (2001), *Methodology for derivation of equipment impairment factors from subjective listening-only tests*.
<<http://www.itu.int/rec/T-REC-P.833>>
- [ITU-T P.833.1] Recommendation ITU-T P.833.1 (2009), *Methodology for the derivation of equipment impairment factors from subjective listening-only tests for wideband speech codecs*.
<<http://www.itu.int/rec/T-REC-P.833.1>>
- [ITU-T P.834] Recommendation ITU-T P.834 (2015), *Methodology for the derivation of equipment impairment factors from instrumental models*.
<<http://www.itu.int/rec/T-REC-P.834>>
- [ITU-T P.834.1] Recommendation ITU-T P.834.1 (2015), *Methodology for the derivation of equipment impairment factors from instrumental models for wideband speech codecs*.
<<http://www.itu.int/rec/T-REC-P.834.1>>

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

LSTR	Listener Sidetone Rating
MOS	Mean Opinion Score
NB	Narrowband
OLR	Overall Loudness Rating
PCM	Pulse Code Modulation
RLR	Receive Loudness Rating
SLR	Send Loudness Rating
STMR	Sidetone Masking Rating
TELR	Talker Echo Loudness Rating
WB	Wideband

5 Conventions

None.

6 WB E-model

6.1 Introduction

The complexity of modern networks requires that, for transmission planning, the many transmission parameters be not only considered individually, but also that their combined effects be taken into account. This can be done by "expert, informed guessing", but a more systematic approach is desirable, such as by using a computational model. The output from the model described here is a scalar transmission rating value, R , which varies directly with the overall conversational quality. [ITU-T G.113] gives guidance about specific impairments, including combined effects based upon a simplification of the model.

6.2 Transmission rating scale of the WB E-model

For the narrowband (NB) case described in [ITU-T G.107], the transmission rating scale ranges from $R = 0$ (lowest possible quality) to $R = 100$ (optimum quality). On this scale, a default NB transmission channel including logarithmic Pulse Code Modulation (PCM) coding and a noise floor (default parameter values according to Table 2 of [ITU-T G.107]) obtains a rating of $R = 93.2$. For a WB speech transmission channel, the quality is generally judged better than that for a NB channel. Thus, this scale range was extended in order to be also applicable to WB transmission scenarios. In the present WB version, the E-model is defined for a WB transmission channel of 50-7000 Hz, as it is defined in [ITU-T G.722].

Unfortunately, it is not possible to obtain direct human judgements on the R -scale, as this scale has additivity properties which are not reflected by ordinary rating scales. Instead, for NB conditions, ITU-T recommends collecting judgements on a 5-point absolute category rating scale, see [ITU-T P.800]. The mean rating, averaged over all test participants and stimuli reflecting the same circuit condition, is then called a mean opinion score (MOS).

It has been shown that MOS ratings differ between tests where only NB stimuli are presented and tests where both NB/WB or purely WB stimuli are presented, as the use of the scale is largely influenced by the stimulus set. On the other hand, there is also experimental evidence that judgements for WB samples collected in a purely WB context do not differ significantly from those collected in a mixed NB/WB context, see [b-Barriac] and [b-Takahashi]. In addition to the stimulus bandwidth, test results are influenced by the test participant group, the language, the participants' native country, etc. [b-Möller-01]. For a NB context, an average S-shaped relationship is defined between the R -scale (range [0;100]) and MOS ratings (range [1;4.5]) collected from "average" test participants in an "average" experimental setting, see Annex B and Appendix I of [ITU-T G.107].

For a WB or a mixed NB/WB context, the R -scale was extended in a way which leaves the NB use of the scale unaffected, including the position of the reference connection (default parameter settings according to Table 2 of [ITU-T G.107]). Such an extension can be based on pairs of auditory tests in which the same (NB) test stimuli have been judged once in a purely NB and once in a mixed NB/WB context. The judgements on these common stimuli define a relationship between the use of the MOS-scale in a NB and in a mixed NB/WB context [b-Raake-01].

Two pairs of tests have been carried out and will be considered in the following. Details on parts of the tests can be found in [b-Möller-02]. The MOS results from these tests have been transformed to the R -scale using the NB transformation rule given in Annex B of [ITU-T G.107]. The resulting R_{NB}

values (NB test) and $R_{NB/WB}$ values (mixed NB/WB test) for the conditions which were common in each pair are displayed in Figure 1.

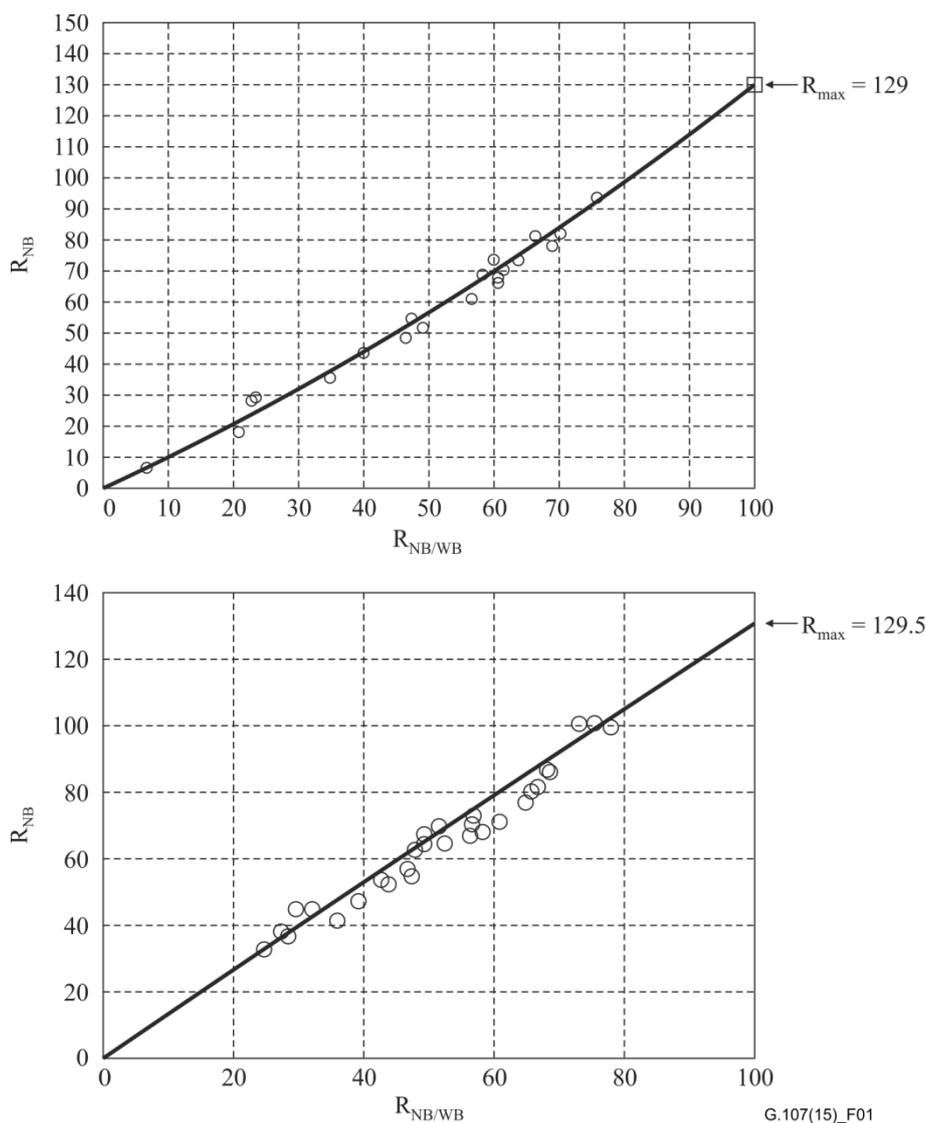


Figure 1 – Comparison between R -values derived in a NB and in a mixed NB/WB context

Due to the use of the NB relationship between MOS and R for deriving the $R_{NB/WB}$ values, the maximum $R_{NB/WB}$ value corresponding to MOS = 4.5 equals 100. The corresponding R_{NB} value of the panels in Figure 1 shows the amount by which the R -scale has to be extended in a NB/WB context. This maximum value is around $R_{max} = 129$. In other words, the NB transmission rating scale of the E-model has been extended by approximately 29% to reflect the quality improvement when migrating from NB to WB. This extended R -scale is a "universal" R -scale and it is applicable to both NB and WB transmission channels.

The primary output of the WB E-model is the transmission rating R . However, the output can also give nominal estimates of user reactions, for instance in the form of MOS values, as described in Annex A.

7 The structure and basic algorithms of the WB E-model

The WB E-model is based on the equipment impairment factor method, following previous transmission rating models. The reference connection, as shown in Figure 2, is split into a send side

and a receive side. The model estimates the conversational quality from mouth-to-ear as perceived by the user at the receive side, both as listener and talker.

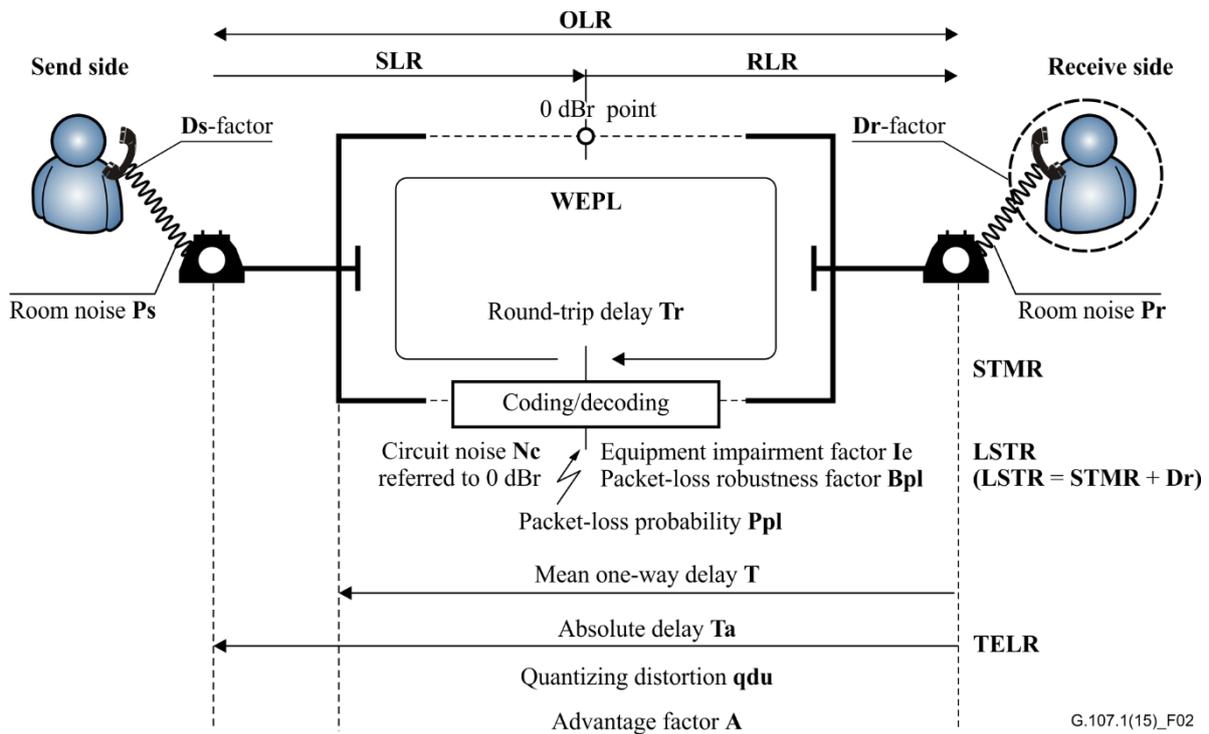


Figure 2 – Reference connection of the WB E-model

The transmission parameters used as an input to the computation model are shown in Figure 2. Values for room noise and for the D -factors are handled separately in the algorithm for the send side and receive side and may be of different amounts. The parameters send loudness rating (SLR), receive loudness rating (RLR) and circuit noise N_c are referred to a defined 0 dBr point. All other input parameters are either considered as values for the overall connection, such as overall loudness rating (OLR) (in any case, the sum of SLR and RLR), equipment impairment factors I_e and advantage factor A , or referred to only for the receive side, such as sidetone masking rating (STMR), LSTR, weighted echo pass loss (WEPL) (for calculation of listener echo) and talker echo loudness rating (TELRL).

There are three different parameters associated with transmission time. The absolute delay T_a represents the total one-way delay between the send side and receive side and is used to estimate the impairment due to excessive delay. The parameter mean one-way delay T represents the delay between the receive side (in talking state) and the point in a connection where a signal coupling occurs as a source of echo. The round-trip delay T_r only represents the delay in a 4-wire loop, where the "double reflected" signal will cause impairments due to listener echo.

Not all parameters listed in Figure 2 are currently used in the WB E-model. However, they are displayed here in order to provide a full description of the transmission channel considering also degradations which might be included in an updated WB E-model at a later stage. The current version is based on [b-Raake-02] and on further extensions for talker echo and delay which have been presented in ITU's Telecommunication Sector (ITU-T).

7.1 Calculation of the transmission rating factor, R

For WB, the basic E-model formula (7-1 of [ITU-T G.107]) can be re-written as:

$$R = R_{o,WB} - I_{s,WB} - I_{d,WB} - I_{e,eff,WB} + A \quad (7-1)$$

$R_{o,WB}$ represents in principle the basic signal-to-noise ratio, including noise sources such as circuit noise and room noise. Factor $I_{s,WB}$ is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor $I_{d,WB}$ represents the impairments caused by delay and the effective equipment impairment factor $I_{e,eff,WB}$ represents impairments caused by low bit-rate codecs. It also includes impairment due to randomly distributed pack losses. The advantage factor A allows for compensation of impairment factors when the user benefits from other types of access. The term $I_{d,WB}$ is subdivided into further specific impairment values. The following clauses give the equations used in the WB E-model.

7.2 Basic signal-to-noise ratio, $R_{o,WB}$

The basic signal-to-noise ratio $R_{o,WB}$ is defined by:

$$R_{o,WB} = 129 \quad (7-2)$$

The effects of circuit noise N_c , room noise at send side P_s and room noise at receive side P_r are items for further study.

7.3 Simultaneous impairment factor, $I_{s,WB}$

The factor $I_{s,WB}$ is the sum of all impairments which may occur more or less simultaneously with the voice transmission. This aspect has not been analysed for the WB case so far, thus it is set to:

$$I_{s,WB} = 0 \quad (7-3)$$

7.4 Delay impairment factor, $I_{d,WB}$

$I_{d,WB}$, the impairment factor representing all impairments due to delay of voice signals, is further divided into the three factors $I_{dte,WB}$, $I_{dle,WB}$ and I_{dd} :

$$I_{d,WB} = I_{dte,WB} + I_{dle,WB} + I_{dd} \quad (7-4)$$

The factor $I_{dte,WB}$ gives an estimate for the impairments due to talker echo:

$$I_{dte,WB} = \left[\frac{R_{oe} - R_{e,WB}}{2} + \sqrt{\frac{(R_{oe} - R_{e,WB})^2}{4} + 100} - 1 \right] (1 - e^{-T}) \quad (7-5)$$

where:

$$R_{oe} = -1.5(N_{o,WB} - RLR) \quad (7-6)$$

$$R_{e,WB} = 80 + 3(TE_{RV,WB} - 14) \quad (7-7)$$

$$TE_{RV,WB} = TELR + K - 40 \log \frac{1 + \frac{T}{10}}{1 + \frac{T}{150}} + 6e^{-0.3T^2} \quad (7-8)$$

For $T < 100$ ms:

$$K = 0.08 \cdot T + 10 \quad (7-9)$$

For $T \geq 100$ ms:

$$K = 18 \quad (7-10)$$

For the WB case, we currently do not assume any mutual influence between talker echo and sidetone.

The factor $Idle, WB$ represents impairments due to listener echo. This impairment has not been specifically studied for the WB case, but it is assumed that the degradations will be similar to those of the NB case, so the formulae are congruent with the ones of the NB E-model:

$$Idle, WB = \frac{Ro, WB - Rle}{2} + \sqrt{\frac{(Ro, WB - Rle)^2}{4} + 169} \quad (7-11)$$

where:

$$Rle = 10.5(WEPL + 7)(Tr + 1)^{-0.25} \quad (7-12)$$

The factor Idd represents the impairment caused by an absolute delay Ta that is too long, which occurs even with perfect echo cancelling.

For $Ta \leq 100$ ms:

$$Idd = 0$$

For $Ta > 100$ ms:

$$Idd = 25 \cdot 1.29 \left\{ (1 + X^6)^{\frac{1}{6}} - 3 \left(1 + \left[\frac{X}{3} \right]^6 \right)^{\frac{1}{6}} + 2 \right\} \quad (7-13)$$

with:

$$X = \frac{\log\left(\frac{Ta}{100}\right)}{\log 2} \quad (7-14)$$

7.5 Equipment impairment factor, Ie, WB

The values for the equipment impairment factor Ie, WB of elements using low bit-rate codecs are not related to other input parameters. They depend on subjective MOS test results as well as on network experience. Refer to Appendix IV of [ITU-T G.113] for the currently recommended values of Ie, WB .

In case of packet-loss, the packet-loss dependent effective equipment impairment factor Ie, eff, WB is derived using the codec-specific value for the equipment impairment factor at zero packet-loss Ie, WB and the packet-loss robustness factor Bpl . With the packet-loss probability Ppl , Ie, eff, WB is calculated using the equation:

$$Ie, effWB = IeWB + (95 - Ie, WB) \cdot \frac{Ppl}{Ppl + Bpl} \quad (7-15)$$

As can be seen from Equation 7-15, the effective equipment impairment factor in case of $Ppl = 0$ (no packet-loss) is equal to the Ie, WB value defined in Appendix IV of [ITU-T G.113].

Corresponding values for Bpl, wb can be found in Appendix IV of [ITU-T G.113].

One should derive $Ie, effWB$ by using the Ie, wb and Bpl values if they are provided in [ITU-T G.113]. If, for practical reasons, it is difficult to observe the packet-loss rate (Ppl), one can use the approach found in [ITU-T P.834.1] to directly derive $Ie, effWB$.

If Ie, wb is derived directly by using the instrumental method recommended in [ITU-T P.834.1], it already reflects the effect of packet-loss introduced in the preparation of speech materials under test. Therefore, one should not use equation (7-15). Rather, one should use the Ie, wb value derived by [ITU-T P.834.1] in $Ie, effWB$ in equation (7-1).

7.6 Advantage factor, A

Background information on the advantage factor A can be found in Appendix II of [ITU-T G.113]. As this effect has not yet been studied for the WB case, it is recommended to set:

$$A = 0 \quad (7-16)$$

7.7 Default values

For all input parameters used in the algorithm of the E-model, the default values are listed in Table 1. It is strongly recommended to use these default values for all parameters which are not varied during planning calculation.

Table 1 – Default values and permitted ranges for the parameters

Parameter	Abbr.	Unit	Default value	Permitted range	Remark
Send loudness rating	SLR	dB	+8	-	(Note 3)
Receive loudness rating	RLR	dB	+2	-	(Note 3)
Sidetone masking rating	STMR	dB	15	10 ... 20	(Note 2)
Listener sidetone rating	LSTR	dB	18	13 ... 23	(Note 2)
D-Value of telephone, send side	Ds	–	3	-	(Note 3)
D-Value of telephone, receive side	Dr	–	3	-	(Note 3)
Talker echo loudness rating	TELR	dB	65	5 ... 65	
Weighted echo path loss	WEPL	dB	110	5 ... 110	
Mean one-way delay of the echo path	T	ms	0	0 ... 500	
Round-trip delay in a 4-wire loop	Tr	ms	0	0 ... 1000	
Absolute delay in echo-free connections	Ta	ms	0	0 ... 500	
Equipment impairment factor	Ie,WB	–	0	0 ... 56	(Note 4)
Packet-loss robustness factor	Bpl	–	4.3	4.3 ... 7.3	(Notes 3, 4)
Random packet-loss probability	Ppl	%	0	0 ... 20	(Notes 3, 4)
Circuit noise referred to 0 dBr-point	Nc	dBm0p	–70	-	(Note 3)
Noise floor at the receive side	Nfor	dBmp	–96	–	(Note 3)
Room noise at the send side	Ps	dB(A)	35	-	(Note 3)
Room noise at the receive side	Pr	dB(A)	35	-	(Note 3)
Advantage factor	A	–	0	0 ... 20	
NOTE 1 – Total values between microphone or receiver and 0 dBr-point.					
NOTE 2 – Fixed relation: LSTR = STMR + D.					
NOTE 3 – Currently under study.					
NOTE 4 – If Ppl > 0%, then the Bpl must match the codec, packet size, and PLC assumed.					

Annex A

MOS values derived from the transmission rating factor R

(This annex forms an integral part of this Recommendation.)

The transmission rating factor R can be in the range from 0 to 129, where $R = 0$ represents an extremely bad quality and $R = 129$ represents a very high quality in the WB case. An estimated mean opinion score (MOS_{CQEW}) for the conversational situation on the scale 1-5 can be obtained from the R -factor by using the equations:

$$Rx = \frac{R}{1.29} \quad (\text{A-1})$$

For $Rx < 0$: $MOS_{CQEW} = 1$

For $0 < Rx < 100$: $MOS_{CQEW} = 1 + 0.035 Rx + Rx(Rx - 60)(100 - Rx)7 \cdot 10^{-6}$ (A-2)

For $Rx > 100$: $MOS_{CQEW} = 4.5$

Bibliography

- [b-ITU-T G.108] Recommendation ITU-T G.108 (1999), *Application of the E-model: A planning guide*.
- [b-ITU-T G.108.1] Recommendation ITU-T G.108.1 (2000), *Guidance for assessing conversational speech transmission quality effects not covered by the E-model*.
- [b-ITU-T G.109] Recommendation ITU-T G.109 (1999), *Definition of categories for speech transmission quality*.
- [b-Barriac] Barriac, V., Le Saout, J.-Y., and Lockwood C. (2004), *Discussion on Unified Methodologies for the Comparison of Voice Quality of Narrowband and Wideband Scenarios*, ETSI Workshop on Wideband Speech Quality in Terminals and Networks: Assessment and Prediction, pp. 75-79.
- [b-Möller-01] Möller, S. (2000), *Assessment and Prediction of Speech Quality in Telecommunications*, Springer.
- [b-Möller-02] Möller, S., Raake, A., Kitawaki, N., Takahashi, A., Wältermann, M. (2006), *Impairment Factor Framework for Wideband Speech Codecs*, IEEE Trans. Audio, Speech and Language Processing 14(6), pp. 1969-1976.
- [b-Raake-01] Raake, A. (2006), *Speech Quality of VoIP – Assessment and Prediction*, Chichester, UK, Wiley.
- [b-Raake-02] Raake, A., Möller, S., Wältermann, M., Côté, N., Ramirez, J.-P. (2010), *Parameter-based Prediction of Speech Quality in Listening Context – Towards a WB E-Model*, in: Second International Workshop on Quality of Multimedia Experience (QoMEX'10), June 21-23, Trondheim, 182-187.
- [b-Takahashi] Takahashi, A., Kurashima, A., and Yoshino, H. (2005), *Subjective Quality Index for Compatibly Evaluating Narrowband and Wideband Speech*, Prague, Czech Republic, MESAQIN.

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