

Recommendation

ITU-T G.113 (09/2024)

SERIES G: Transmission systems and media, digital systems and networks

International telephone connections and circuits – General Recommendations on the transmission quality for an entire international telephone connection

Transmission impairments due to speech processing

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Recommendation ITU-T G.113

Transmission impairments due to speech processing

Summary

Recommendation ITU-T G.113 provides guidance regarding transmission impairments introduced by digital speech processing systems. The information provided is for use in conjunction with the transmission planning approach described in Recommendations ITU-T G.107, ITU-T G.108 and ITU-T G.109. The impairment factor method, used by the E-model of Recommendation ITU-T G.107, is now recommended. The earlier method that used quantization distortion units is no longer recommended. Updated impairment factor values for various digital processing systems are provided in Appendix I. Appendix II contains guidance on how an advantage factor can be used to reflect the variation in user expectation of quality for different communications systems (e.g., mobile). Appendix III provides guidelines regarding individual transmission impairment parameters other than *qdu* and equipment impairment factor, and Appendix IV gives provisional planning values for the wideband equipment impairment factor and Appendix V gives provisional planning values for the fullband equipment impairment factor.

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FOREWORD

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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.

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Recommendation ITU-T G.113

Transmission impairments due to speech processing

1 Scope

This Recommendation provides guidance regarding transmission impairments introduced by digital speech processing systems. The information provided is for use in conjunction with the transmission planning approach described in [ITU-T G.107], [ITU-T G.108] and [ITU-T G.109]. The impairment factor method, used by the E-model of [ITU-T G.107], is now recommended. The earlier method that used quantization distortion units is no longer recommended.

The E-model reflects the combined perceptual effects of different types of impairments on the end-to-end speech transmission performance by using impairment factors. Impairment factors represent the (degrading) contribution of one instrumentally measurable attribute of the connection (e.g., attenuation, loss), or of a complete piece of equipment (e.g., a low bit-rate coding and decoding process) on the overall quality as experienced by the user. This degradation is called an "impairment factor" in a general sense, and "equipment impairment factor" when it is related to the degradations due to a specific piece of equipment.

The E-model is highly useful because it combines the effects of different impairment factors.

Network and service planners who are concerned with end-to-end speech transmission performance can use impairment factors with the E-model to assess the effects of introducing speech processing technologies.

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.

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| [ITU-T G.107] | Recommendation ITU-T G.107 (2015), <i>The E-model: a computational model for use in transmission planning</i> . |
| [ITU-T G.108] | Recommendation ITU-T G.108 (1999), <i>Application of the E-model: A planning guide</i> . |
| [ITU-T G.109] | Recommendation ITU-T G.109 (1999), <i>Definition of categories of speech transmission quality</i> . |
| [ITU-T G.168] | Recommendation ITU-T G.168 (2015), <i>Digital network echo cancellers</i> . |
| [ITU-T G.711] | Recommendation ITU-T G.711 (1988), <i>Pulse code modulation (PCM) of voice frequencies</i> . |
| [ITU-T G.712] | Recommendation ITU-T G.712 (2001), <i>Transmission performance characteristics of pulse code modulation channels</i> . |
| [ITU-T G.792] | Recommendation ITU-T G.792 (1988), <i>Characteristics common to all transmultiplexing equipments</i> . |
| [ITU-T O.132] | Recommendation ITU-T O.132 (1988), <i>Quantizing distortion measuring equipment using a sinusoidal test signal</i> . |

[ITU-T P.833]	Recommendation ITU-T P.833 (2001), <i>Methodology for derivation of equipment impairment factors from subjective listening-only tests</i> .
[ETSI ETR 250]	ETSI ETR 250 (1996), <i>Transmission and Multiplexing (TM); Speech communication quality from mouth to ear for 3,1 kHz handset telephony across networks</i> .
[ETSI TR 102 356]	ETSI TR 102 356 V1.1.1 (2004), <i>Speech Processing, Transmission and Quality Aspects (STQ); Application and enhancements of the E-model (ETR 250); Overview of available documentation and ongoing work</i> .

3 Definitions

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

EPF	Error Protection File
GoB	Good or Better
MOS	Mean Opinion Score
PoW	Poor or Worse
PSTN	Public Switched Telephone Network
qdu	Quantization distortion unit
VAD	Voice Activity Detection

5 Conventions

None.

6 Basic planning principle

The rapidly changing scenario in the field of multiple interconnected networks with increasing size and complexity – in combination with new technologies and the constraint for more economical solutions – requires more flexibility with respect to transmission planning.

In general, the quality of speech transmission via telephone channels is based on a subjective judgment by the users at both ends. Therefore, traditionally, transmission was – in principle – derived from an end-to-end consideration in conjunction with a partitioning of all relevant parameters between different networks or parts of a network. As networks become more complex (e.g., the proliferation of digital mobile access networks and networks that transport voice calls as packets) this approach is no longer applicable.

Accordingly, the recommended planning approach is to use the impairment factor method (see clause 8) in conjunction with the E-model (see [ITU-T G.107]).

A fundamental purpose of network planning is to control the summation of transmission impairments caused by the different network elements in all possible configurations. It is not the task of network planning to limit the transmission impairment of a specific network element. Unless indicated otherwise, it is assumed that transmission, switching and terminal elements in general are designed to meet all relevant requirements as given in ITU-T Recommendations and in international or national standards applicable for this type of element.

In auditory tests – using human subjects – estimates of the integral quality, thus covering different quality dimensions, are often expressed in terms of mean opinion score (MOS), percentage good or better (%GoB) or percentage poor or worse (%PoW). During transmission planning, however, it is not practical to perform subjective tests. Therefore, a method must be provided which enables the planner to combine by calculation all existing transmission impairments in the given connection to a total value of impairment. This calculation must be performed by using an algorithm based on subjective testing. In telephone connections consisting of a variety of network elements, different transmission parameters may also simultaneously contribute to the total impairment. Therefore, the planning method used must also incorporate combination effects. For all configurations, the planning of speech transmission quality should be based on an end-to-end consideration rather than on a specification of individual objective parameter limits.

For the calculation of the different impairment values, particularly if the combined effect from the presence of more than one parameter needs to be considered, computational models are used for planning purposes. Several such "rating-models" have been developed and were contained and described in former ITU-T publications, which are no longer recommended for application and which today have bibliographic status only. Today, [ITU-T G.107] gives the algorithm for the so-called E-model as the common ITU-T transmission rating model.

Transmission planning based on the E-model – as recommended – provides a prediction of the expected quality – as perceived by the user – for an investigated connection. Based on an end-to-end assessment for each transmission parameter (including the type and number of low bit-rate codecs) impairment values are derived. This model accounts for low bit-rate coding devices as well as for impairments introduced by standard PCM coders and for impairments not directly related to digital processing (e.g., environmental noise).

The basic planning principle – as recommended – deviates from previous planning methods for network interconnection scenarios. End-to-end speech transmission quality is now expressed in terms of the E-model rating R , as a result of calculations with the E-model. The E-model rating R can be transformed into other quality measures, which have been used in transmission planning before, such as MOS, %GoB or %PoW, according to Annex B of [ITU-T G.107].

7 The impairment factor method

According to the impairment factor method, the fundamental principle of the E-model is based on a concept given in the description of the OPINE model [b-ITU-T P-series Supp.3], which states that transmission impairments can be transformed into "psychological factors"; and psychological factors on the psychological scale are additive.

The impairment factor method allocates a value of impairment to each parameter and then allows the simple addition of these impairments to determine the overall impairment. It should be noted that the impairment factor allocation can only be made by using subjective mean opinion score test results.

The result of any calculation with the E-model is the E-model rating R , which combines all transmission parameters relevant for the considered connection. [ITU-T G.107] provides details on how this E-model rating R is composed.

8 Equipment impairment factor, I_e

Modern coding laws, like those associated with low bit-rate codecs as described in the ITU-T G.720-series Recommendations or the GSM Standards, as well as ADPCM with different operating bit-rates, will contribute with distortions resulting in a decrease of the perceived speech transmission quality. In contrast to the quantization distortion due to the standard 8-bit PCM coding (A-law or μ -law), these impairments cannot readily be quantified with a number of quantization distortion unit (qdu) (see clause 9). Following the considerations of clause 1, the impairments introduced by different types of low bit-rate codecs are expressed by an "equipment impairment factor", I_e . This factor should

ideally cover all perceptively very diverse effects (distortion, sound degradation, degradation of voice quality, etc.) which can be associated with the codec used in the connection, except those already covered in another way by the E-model (e.g., overall attenuation, absolute delay). *I_e* values can be determined in auditory tests carried out according to a methodology given in [ITU-T P.833].

For end-to-end transmission planning with the E-model, each codec can be assigned an equipment impairment factor which forms an input parameter to the E-model. For asynchronously working tandems of different types of codecs, or of several codecs of the same type, the underlying additivity of the E-model (see the "impairment factor principle" cited in clause 1) is assumed to be valid as well, i.e., the respective equipment impairment factors are added on the scale of the transmission rating R.

In Annex G of [ETSI ETR 250], comparisons have been made between subjective and predicted MOS values for various combinations of codecs. In general, the agreement is quite good, better than when the qdu method is applied.

For an overview of documentation related to the E-model, see [ETSI TR 102 356].

For up-to-date information on values for the equipment impairment factor, Appendix I provides guidance. Appendix I is intended to be updated regularly.

9 Quantization distortion unit

The qdu concept is not applicable for low bit-rate codecs.

A quantization distortion unit (qdu) was defined in 1982 as equivalent to the distortion that results from a single encoding (A/D) and decoding (D/A) by an average G.711 codec. Such a device has a signal/distortion ratio of 35 dB when measured according to [ITU-T O.132].

Conceptually, the number of qdus assigned to a particular PCM process should reflect the effect of only the quantization noise produced by the PCM process on speech. In practice, the qdus must be determined from subjective measurements of real or simulated processes, where subjects will be exposed to not only the quantization noise but to other impairments produced by the digital process tested, including the departures from ideal frequency response in the anti-aliasing and reconstruction filters.

The qdu was the traditional parameter used for evaluating digital transmission impairments and this parameter is still useful for the characterization of transmission, network and terminal elements that do incorporate pure PCM processes according to [ITU-T G.711].

Formerly, the qdu was the basis for an end-to-end transmission planning of impairments due to digital processes, known as the "14 qdu rule"; this approach is no longer recommended by ITU-T. Nevertheless, today the qdu functions rather as an input parameter for E-model calculations of end-to-end speech transmission performance.

The units of quantization distortion (qdu) assigned to a number of PCM processes are given in Table 9-1. Background information on these assignments is given in the notes associated with Table 9-1.

Table 9-1 – Planning values for quantization distortion (see Notes 1, 7 and 8)

PCM process	Quantization distortion units (qdu)	Notes
8-bit PCM codec-pair (according to [ITU-T G.711], A- or μ -law)	1	(2, 3)
Transmultiplexer pair based on 8-bit PCM, A- or μ -law (according to [ITU-T G.792])	1	(3)
Digital loss pad (A- or μ -law)	0.7	(4)