The E-model

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E-Model Tutorial

Background

The E-Model (**ITU-T Rec. G.107** [1]) is a transmission planning tool that provides a prediction of the expected voice quality, as for a complete end-to-end (i.e. mouth-to-ear) telephone connection under conversational conditions. The E-Model takes into acc impairments, in particular the impairment due to low bit-rate coding devices and one-way delay, as well as the "classical" teleph echo. It can be applied to assess the voice quality of wireline and wireless scenarios, based on circuit-switched and packet-switc

The E-Model is not a true psycho-physical model, and cannot be used to accurately predict the absolute opinion of an individual users, the results are sufficiently accurate for transmission planning purposes. The E-model may also be useful for quality monit are no agreed-upon methods and procedures for such an application of the E-model. The current methods for voice quality mon described in **ITU-T Rec. P.561** and **ITU-T Rec. P.562**, with the exception of the overall voice quality for Voice over IP, for whi method.

The E-Model is based on modeling the results from a large number of subjective tests done in the past on a wide range of trans output of the E-Model calculations is a scalar quality rating value known as the "Transmission Rating Factor, R". R can be transf such as Mean Opinion Score (MOS-CQE [2]), Percentage Good or Better ((GoB) or Percentage Poor or Worse ((PoW). However, comparing these transformed measures with values of MOS, %GoB or %PoW from other sources, which may not have been obt

The E-Model is based on a mathematical algorithm, with which the individual transmission parameters are transformed into diffe that are assumed to be additive on a psychological scale. The algorithm of the E-Model also takes into account the combination connection which occur simultaneously, as well as some masking effects. To the extent that impairments are present for which maintained, E-model predictions may be inaccurate.

The relation between the different impairment factors and R is given by the equation:

$$R = Ro - Is - Id - Ie,eff + A$$

where:

The term Ro expresses the basic signal-to-noise ratio (received speech level relative to circuit and acoustic noise).

The term Is represents all impairments that occur more or less simultaneously with the voice signal, such as: too lo non-optimum sidetone (STMR), quantization noise (qdu), etc.

The term Id sums all impairments due to delay and echo effects.

The term Ie,eff is an "effective equipment impairment factor", which represents impairments caused by low bit-rate due to packet-losses of random distribution. Values of Ie for specific codecs without packet loss are given in **ITU-T I** values are transformed to Ie,eff in case of random packet loss, using the E-model algorithm.

The term A is an "advantage factor", which allows for an "advantage of access" for certain systems relative to conve for convenience. While all other impairment factors are subtracted from the basic signal-to-noise ratio Ro, A is adde impairments to a certain amount. It can be used to take into account the fact that the user will tolerate some decrea exchange for the "advantage of access". Examples of such advantages are cordless and mobile systems or connectio multi satellite hops.

Values of R fall in the range of $0 \leq R < 100$, with higher values indicating higher speech quality. Table 1, taken from **ITU-T Rec** Ratings R to categories of speech transmission quality and to user satisfaction.

Table 1 - Definition of categories of speech transmission quality

Range of E-Model Rating R	Speech transmission quality category	User satisfac
$90 \leq R < 100$	Best	Very satisfied
$80 \leq R < 90$	High	Satisfied

70 ≤ R < 80	Medium	Some users dissatisfied
60 ≤ R < 70	Low	Many users dissatisfied
50 ≤ R < 60	Poor	Nearly all users dissatisfi
NOTE 1 – Connections with E-Model Ratings R below 50 are not recommended. NOTE 2 – Although the trend in transmission planning is to use E-Model Ratings R, equations to convert Ratings R into other metrics, e.g. %MOS, %GoB, PoW can be found in **ITU-T Rec. G.107 Annex B** [1].		

Application of the E-Model

Figure 1 shows the basic reference configuration used by the E-model for estimating end to end speech quality, with the parame

- SLR Send Loudness Rating
- RLR Receive Loudness Rating
- OLR Overall Loudness Rating[1]
- STMR Sidetone Masking Rating[2]
- LSTR Listener Sidetone Rating[2]
- Ds D-value of telephone at send-side
- Dr D-value of telephone at receive-side[2]
- TELR Talker Echo Loudness Rating
- WEPL Weighted Echo Path Loss
- T Mean one way delay of the echo path
- Tr Roundtrip delay in a closed 4-wire loop
- Ta Absolute one-way delay in echo free connections
- qdu Number of quantization distortion units
- Ie Equipment impairment factor
- Ppl Random packet-loss probability
- Bpl Packet-loss robustness factor
- Nc Circuit noise referred to the 0 dBr-point
- Nfor Noise floor at the receive-side
- Ps Room noise at the send-side
- Pr Room noise at the receive-side
- A Advantage factor

The connection is basically divided into a "send side" (subscript $_S$) and a "receive side" (subscript $_R$) with a virtual centre referre most important assumptions in the model is that the perceived quality is referred to the user on the "receive side", with this use conditions (talking and listening). This is important when inputting parameters relating to listening (loudness, equipment impair sidetone, delay, echo etc).

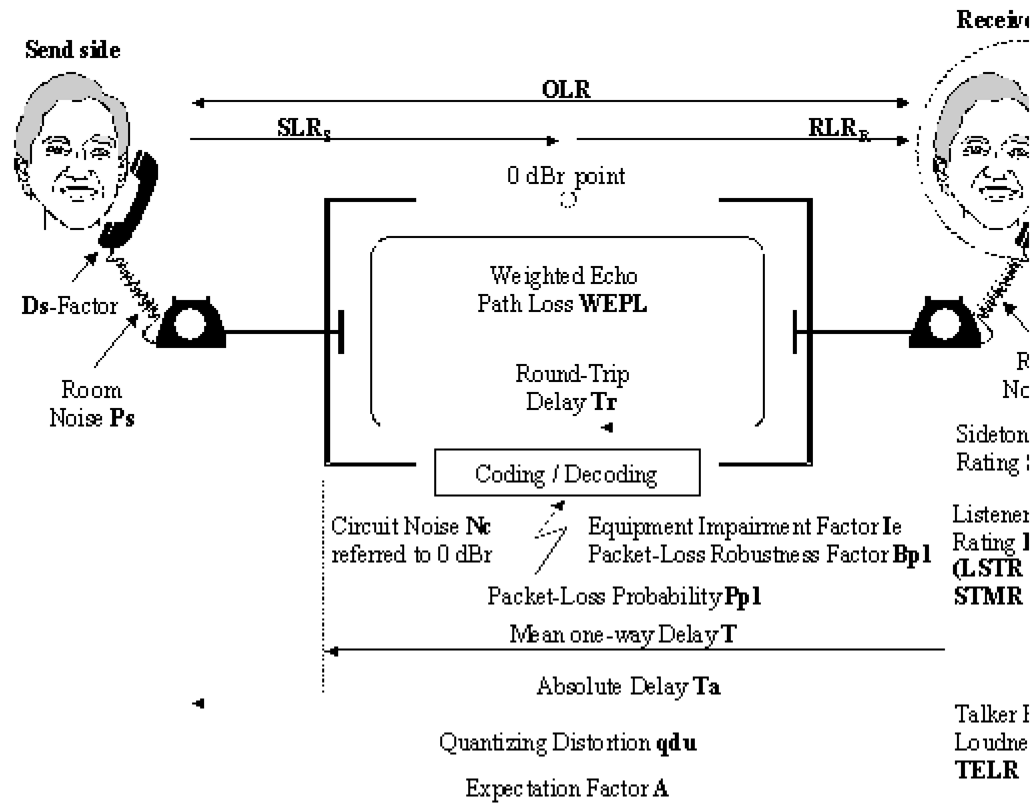

Figure 1 - Basic reference configuration of the E-Model

Values of SLR, RLR and Nc must be referred to a 0 dBr-point (i.e. any gains or losses taken into account). For the basic end to e

To evaluate the impairment due to talker echo, the E-Model expects two parameters, the mean one-way echo path delay (T), ar (TELR) of the echo path. It is very important to note that talker echo is referred to the user on the receive side. The value for TE according to the basic formula:

$$TELR = SLR_R + EL + RLR_R$$

where: EL (Echo Loss), represents the effective echo return loss seen by the receive side.

To evaluate the impairment due to one-way delay in the absence of echo, two approaches may be used:

i. Input the required value of Ta and set T = Tr = 0. This effectively turns "off" the echo algorithm and can be considere

ii. It may be more realistic to input the required value of Ta and set T = Tr/2 = Ta, with TELR and WEPL set to their defa practical case of a near-ideal echo canceller.

Default values for all E-Model parameters and nominal parameter ranges3 are listed in Table 2. With these default values, the re

Table 2 - Default values and recommended ranges for the parameters

Parameter	Abbr.	Unit	Default value	Recomme
Send Loudness Rating	SLR_S	dB	+8	0 tc
Receive Loudness Rating	RLR_R	dB	+2	–5 t
Sidetone Masking Rating	STMR	dB	15	10
Listener Sidetone Rating	LSTR	dB	18	13
D-value of telephone, send side	Ds	–	3	–3
D-value of telephone receive side	Dr	–	3	–3
Talker Echo Loudness Rating	TELR	dB	65	5 t
Weighted Echo Path Loss	WEPL	dB	110	5 tc
Mean one-way delay of the echo path	T	ms	0	0 tc
Round trip delay in a 4-wire loop	Tr	ms	0	0 to
Absolute delay in echo free connections	Ta	ms	0	0 tc
Number of Quantization distortion units	qdu	–	1	1 t
Equipment impairment factor	Ie	–	0	0 t
Packet-loss Robustness Factor	Bpl	–	1	1 t
Random Packet-loss Probability	Ppl	%	0	0 t
Circuit noise referred to 0 dBr-point	Nc	dBm0p	–70	–80

Noise floor at the receive Side	Nfor	dBmp	–64	
Room noise at the send side	Ps	dB(A)	35	35
Room noise at the receive side	Pr	dB(A)	35	35
Advantage factor	A	–	0	0 t
NOTE 1 – Total values between microphone or receiver and 0 dBr-point. NOTE 2 – Fixed relation: LSTR = STMR + D. NOTE 3 – Currently under study.				

The **Calculation Tool** that is provided here implements the basic E-Model calculation, based on the latest version [1].

The **Graphical tool** contains icons of the various elements of the network you wish to simulate. These icons have knowledge of element and feed the E-Model tool with appropriate values.

References

[1] "The E-model, a computational model for use in transmission planning" **ITU-T Rec. G.107**
[2] "Mean Opinion Score (MOS) terminology" **ITU-T Rec. P.800.1**
[3] "Provisional planning values for the equipment impairment factor Ie and packet-loss robustness factor Bpl" **ITU-T Rec. G.1**
[4] "Definition of categories of speech transmission quality" **ITU-T Rec. G.109**

Recommended bibliography

The following references provide more details on the E-Model and its application.

"Application of the E-Model - A Planning Guide" **ITU-T Rec. G.108**

"Guidance for assessing conversational speech transmission quality effects not covered by the E-Model" **ITU-T Rec. G.108.1**

"Transmission and Multiplexing (TM); Speech communication quality from mouth to ear for 3.1 kHz handset telephony across ne

"The ETSI Computation Model: a Tool for Transmission Planning of Telephone Networks", N.O. Johannesson, IEEE Communicatio

"Voice Quality Recommendations for IP Telephony" TIA/EIA/TSB116 (March 2001) **http://www.tiaonline.org/standards/ip**

[1] No direct input value; calculated as OLR = SLR_S + RLR_R.
[2] These parameters have a fixed relation by: LSTR = STMR + Dr.
[3] The E-Model is not validated outside of these ranges