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NETWORKS

Measurements related to speech loudness

Calculation of loudness ratings for telephone sets

ITU-T Recommendation P.79

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ITU-T Recommendation P.79

Calculation of loudness ratings for telephone sets

Summary

ITU-T Recommendation P.79 describes the preferred method for calculating loudness ratings mainly in the case of local telephone systems which transmit a band of frequencies not exceeding about 180-4500 Hz.

The purpose of using loudness ratings for telephone sets is two-fold: first, to provide the transmission planner with an adequate measure of how the sets perform in the network; second, to enable valid and unambiguous comparison between sets. Therefore, to avoid confusion, this version of this Recommendation contains only those telephone set loudness ratings which are of interest for these purposes.

The current revision of ITU-T Recommendation P.79 is intended to clarify the application fields for Annexes A and G.

This Recommendation incorporates in Annex A the description of narrow-band loudness ratings which is applicable for narrow-band and "dual-mode" narrow-band/wideband end-to-end transmission, including terminals.

Annex G is intended to apply only for end-to-end wide-band transmission (100 Hz to 7 kHz) between wideband terminals.

Source

ITU-T Recommendation P.79 was approved on 13 November 2007 by ITU-T Study Group 12 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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ITU-T Recommendation P.79

Calculation of loudness ratings for telephone sets

1 Scope

This Recommendation describes the preferred method for calculating loudness ratings in the following cases:

- Narrow-band local telephone systems (which transmit a band of frequencies not exceeding about 180-4500 Hz).
- "Dual-Mode" narrow-band/wideband end-to-end transmissions, including terminals, (respectively 300-3400 Hz and 100-7000 Hz).
- Wide-band only end-to-end transmission (100 Hz to 7 kHz) between wide-band terminals.

The purpose of using loudness ratings for telephone sets is two-fold: first, to provide the transmission planner with an adequate measure of how the sets perform in the network; second, to enable valid and unambiguous comparison between sets. Therefore, to avoid confusion, this version of this Recommendation contains only those telephone set loudness ratings which are of interest for these purposes.

Annex A contains the fundamental principles of loudness rating calculations and explains the relations between [ITU-T P.76], [ITU-T P.78] and this Recommendation as well as the physical basis of this Recommendation.

Annex B explains the fundamental concept of the sidetone masking rating (STMR) used for evaluation of the talker's sidetone.

Annex C gives an alternative form of the loudness rating algorithm which is useful for estimating the relative importance of how the sensitivity in different frequency bands influences the loudness rating value.

Annex D provides, as a reference only, W_i -weights for OLR, SLR and RLR over the wider band 100-8000 Hz.

Annex E describes how the listener's sidetone factor D can be determined.

Annex F shows how the sidetone sensitivity S_{meST} can be computed from the send and receive sensitivity and impedance data.

Annex G gives a set of W weights suitable for the calculation of sending and receiving loudness ratings of wideband (100 to 7000 Hz) only terminals.

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.111] ITU-T Recommendation G.111 (1993), *Loudness ratings (LRs) in an international connection*.

[ITU-T P.48] ITU-T Recommendation P.48 (1988), *Specification for an intermediate reference system*.

[ITU-T P.51]	ITU-T Recommendation P.51 (1996), <i>Artificial mouth</i> .
[ITU-T P.57]	ITU-T Recommendation P.57 (2005), <i>Artificial ears</i> .
[ITU-T P.64]	ITU-T Recommendation P.64 (2007), <i>Determination of sensitivity/frequency characteristics of local telephone systems</i> .
[ITU-T P.76]	ITU-T Recommendation P.76 (1988), <i>Determination of loudness ratings; fundamental principles</i> .
[ITU-T P.78]	ITU-T Recommendation P.78 (1996), <i>Subjective testing method for determination of loudness ratings in accordance with Recommendation P.76</i> .
[ITU-T P.310]	ITU-T Recommendation P.310 (2003), <i>Transmission characteristics for telephone band (300-3400 Hz) digital telephones</i> .
[ITU-T P.340]	ITU-T Recommendation P.340 (2000), <i>Transmission characteristics and speech quality parameters of hands-free terminals</i> .
[ITU-T Handbook]	ITU-T <i>Handbook on Telephonometry</i> , 1992.

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

JLR	Junction Loudness Rating
LSTR	Listener Sidetone Rating
OLR	Overall Loudness Rating
RLR	Receive Loudness Rating
SLR	Send Loudness Rating
STMR	Sidetone Masking Rating

4 Loudness rating parameters for telephone sets

In transmission planning and for regulatory purposes, the following loudness rating parameters for telephone sets are of interest:

- send loudness rating (SLR);
- receive loudness rating (RLR).

For 2-wire sets, SLR and RLR are to be determined for an appropriate range of feeding currents and subscriber cables.

The *talker's sidetone* is characterized by the *sidetone masking rating (STMR)*, usually determined for a representative range of terminations.

The *listener's sidetone* is characterized by the *listener's sidetone rating (LSTR)*, which is a characterization of the room noise picked up via the electric sidetone path. However, in transmission planning it is often more useful to evaluate listener's sidetone performance of a set indirectly by the difference:

$$D = \text{LSTR} - \text{STMR}$$

D is a parameter of the telephone set which is *independent* of the termination. Therefore, the formulae for calculation of D are given in Annex E.

5 General algorithm for loudness rating calculations

The general algorithm for calculation of loudness ratings (LRs) is of the form:

$$LR = -\frac{10}{m} \cdot \log_{10} \sum_{i=N_1}^{N_2} 10^{0.1 \cdot m(S_i - W_i)} \quad (5-1)$$

where:

m a constant (in the order of 0.2).

The summation is to be performed at frequencies F_i , spaced 1/3 octave apart.

W_i weighting coefficient (different for the various LRs).

S_i the sensitivity at frequency F_i of the electro-acoustic path under consideration.

NOTE 1 – S_i is to be determined by the methods described in [ITU-T P.64] for analogue 2-wire handsets. Digital sets are measured according to clause B.6 of [ITU-T P.310] and hands-free sets according to clause 4.5.1 of [ITU-T P.340].

NOTE 2 – One can also use the designation "electro-acoustic loss" $L_i = -S_i$.

NOTE 3 – When calculating SLR and RLR, one must only include those parts of the frequency band where an actual signal transmission can occur in order to ensure that the additivity property of LRs is retained. Therefore, only the frequency band 200-4000 Hz is used.

6 Calculation of SLR and RLR

In Equation 5-1, $m = 0.175$.

The weighting coefficients W_{si} and W_{ri} are given in Table 1.

Table 1 – Weighting factors W_i for SLR and RLR

Band No.	Mid-frequency (Hz)	Send W_{si}	Receive W_{ri}
4	200	76.9	85.0
5	250	62.6	74.7
6	315	62.0	79.0
7	400	44.7	63.7
8	500	53.1	73.5
9	630	48.5	69.1
10	800	47.6	68.0
11	1000	50.1	68.7
12	1250	59.1	75.1
13	1600	56.7	70.4
14	2000	72.2	81.4
15	2500	72.6	76.5
16	3150	89.2	93.3
17	4000	117.0	113.8

NOTE – These weights are 0.3 dB smaller than those provided in the original version of this Recommendation in the CCITT *Blue Book*, Vol. V, to allow for the change in loudness of the IRS over the reduced bandwidth.

The S_i -values apply as follows.

For SLR from the artificial mouth to an (equivalent) 600-ohm electrical interface:

$$S_i = S_{mJ}(F_i) \quad (6-1)$$

For RLR from an (equivalent) 600-ohm electrical interface to the artificial ear, including a consideration of the earcap leakage L_E :

$$S_i = S_{Je}(F_i) - L_E(F_i) \quad (6-2)$$

Normally, the receive sensitivity is measured with the artificial ear acoustically sealed to the earcap (see [ITU-T P.64]). If the earcap is of a conventional shape and the receiver is somewhat similar to the type used in the IRS, the L_E -values in Table 2 are to be used.

Table 2 – Leakage correction L_E used for sealed measurements on an IRS-type receiver

Frequency (Hz)	L_E (dB)	Frequency (Hz)	L_E (dB)
200	8.4	1000	−2.3
250	4.9	1250	−1.2
315	1.0	1600	−0.1
400	−0.7	2000	3.6
500	−2.2	2500	7.4
630	−2.6	3150	6.7
800	−3.2	4000	8.8

If a more advanced artificial ear, incorporating a simulated leak, is used, no L_E -correction is needed, i.e., $L_E = 0$ in Equation 6-2. (See also [ITU-T P.57].)

Also for hands-free telephones, $L_E = 0$.

7 Calculation of STMR

In Equation 5-1, $m = 0.225$.

The weighting coefficients W_{MSI} are given in Table 3.

The S_i -values apply from the artificial mouth to the artificial ear (for the same set) via the electric sidetone path, caused by impedance mismatches for analogue 2-wire sets or a designed bridging circuit between send and receive for digital sets.

$$S_i = S_{meST}(F_i) \quad (7-1)$$

NOTE – Most often the sidetone measuring set-up consists of an unloaded subscriber line (or its electrical equivalent) terminated by a physical, nominal impedance which may be complex. Then the curve $S_{meST}(f)$ can be adequately represented by the frequency points spaced 1/3 octave apart. However, if the termination consists of a 2-wire port of a digital exchange, the sidetone response $S_{meST}(f)$ may vary very rapidly with frequency, so that the 1/3-octave spacing is too coarse. This happens when the loss through the exchange is low and there are strong reflections at the other 2-wire port of the connection. In this case, a talker would notice both sidetone and echo so that a formal calculation of STMR is less relevant.

Table 3 – Weighting factors W_{MSI} for STMR

Band No.	Mid-frequency (Hz)	W_{MSI}
(1)		(2)
1	100	110.4
2	125	107.7
3	160	104.6
4	200	98.4
5	250	94.0
6	315	89.8
7	400	84.8
8	500	75.5
9	630	66.0
10	800	57.1
11	1000	49.1
12	1250	50.6
13	1600	51.0
14	2000	51.9
15	2500	51.3
16	3150	50.6
17	4000	51.0
18	5000	49.7
19	6300	50.0
20	8000	52.8

8 Calculation of LSTR

With the exception of S_i , the procedure is the same as for STMR, i.e., $m = 0.225$ and the weighting factors are as given in Table 3.

The S_i -values apply from a diffuse sound source to the artificial ear via the electric sidetone path. (The diffuse field sound pressure level is measured at the artificial mouth MRP in the absence of the artificial mouth.) See clause 11 of [ITU-T P.64]. See also [ITU-T Handbook].

$$S_i = S_{RNST}(F_i) \quad (8-1)$$

NOTE 1 – If the microphone and/or its associated circuitry are non-linear, both the artificial voice and the diffuse sound must consist of properly shaped speech band noise sources.

NOTE 2 – Diffuse sound field sidetone signals can have rather low levels in certain frequency bands which may cause accuracy problems in the measurements.

NOTE 3 – Annex E describes the calculation of listener's sidetone factor D which can be used practically to estimate LSTR from STMR.

Annex A

Fundamental principles of loudness rating calculations

(This annex forms an integral part of this Recommendation)

A.1 Introduction

Loudness ratings according to the principles described in [ITU-T P.76] can be determined without recourse to subjective tests provided that all the following conditions are fulfilled:

- a) a theoretical model is available having a suitable structure;
- b) the appropriate values of the essential parameters of the model are known;
- c) the sending and receiving sensitivities of the intermediate reference systems are known;
- d) the sending and receiving sensitivities of the "unknown" local telephone systems and the insertion loss of the intervening chain of circuits are known.

The methods of determining sending and receiving sensitivities using an artificial mouth and artificial ear are defined in [ITU-T P.64]. The characteristics of the intermediate reference system determined according to the same methods are given in [ITU-T P.48]. The receiving sensitivities obtained using the artificial ear now mentioned in [ITU-T P.64] are not directly suitable for use in calculating loudness ratings but must be corrected to allow for differences between sound pressures in real ears under conditions of telephone conversations and those measured by the artificial ear.

A.2 Definitions and symbols concerning sound pressures, sensitivities and transmission losses

Definitions and symbols used in the subsequent description of theoretical principles are listed below and are illustrated in Figure A.1.

A.2.1 Concerning talking

These definitions and symbols characterize the situation where a subject is talking, and they include the subject's physical relationship to the telephone or reference connection.

MRP Point defining the mouth reference point; MRP is at a defined location relative to the talker's lips. (See [ITU-T P.64]).

p_M Sound pressure at MRP¹ in absence of any obstruction.

B'_S Spectrum density (long-term mean pressure)² of speech referred to a MRP in dB relative to 20 μ Pa in a bandwidth of 1 Hz.

VL Vocal level, i.e., speech sound pressure (long-term rms while talker is active) level of talker at the MRP; usually referred to a reference vocal level as datum.

SP Speaking position, i.e., the relative location of the microphone of the telephone or reference system and the lips of the talker.

¹ The reference level or datum must be specified, e.g., 1 Pa, 20 μ Pa, etc.

² In practice, measurements are made in terms of sound pressure, and that convention is retained for convenience of explanation. It is worth noting that sound pressure relative to 20 μ Pa in a bandwidth of 1 Hz is approximately equal to sound intensity relative to 1 pW/m² per Hz.