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6 Algorithms for transmission planning (from Ellemtel, Sweden)

This Section compares loudness ratings calculated by algorithms as defined in the IEEE, the OREM-8 and the Recommendation P.79 standards with P.79A, an adaptation of Recommendation P.79 for transmission planning. The computations encompassed 71 different telephone set characteristics and 27 cases of subscriber cable attenuation distortions.

The results show that, in typical transmission planning situations, the loudness ratings by P.79A are closely related to the others. In addition, P79A has the best additivity accuracy and the simplest form. Administrations are therefore urged to make some comparative studies using this P.79A algorithm in transmission planning.

6.1 *Introduction*

Some preliminary comparisons between different loudness loss estimation methods for telephone network transmission planning are presented (sidetone algorithms are not treated, however). The methods discussed are all based on objective measurements on telephone instruments.

The transmission planner has some basic requirements:

1) to obtain a meaningful and reliable indication of the telephone speech transmission quality as regards the acoustic loss between the talking subscriber’s mouth and the listening subscriber’s ear;

2) to characterize the individual parts of a connection by numerical values in such a way that their sum equals the acoustic loss measure of the complete connection;

3) to ensure that the numerical values can be determined reliably, inexpensively and with sufficient accuracy from measurements.

The third requirement means that for quality control and day-to-day use only *objective* | electro-acoustic measurements can be considered. Of course, subjective measurements have been absolutely necessary in the past to establish the general level of reference. But they are more costly to carry out and give far less repeatable results even under favourable conditions. For example the CCITT Laboratory has periodically made subjective reference equivalence measurements on the same stable telephone set since late 1981. The values seem to wander slowly with time within a 3 dB range. See [12].

6.2 *Different loudness rating methods*

Objective electroacoustic loss (or sensitivity) measurements form the basis of several planning methods used by Administrations for their national networks. The most important of these ‘‘loudness ratings’’ are listed below, in the order most widely applied.

1) *IEEE standard* . This is now used in the USA and Canada. It is well-documented and reliably instrumented (see § 1 and [1]).

2) *OREM-B standard* | (in different versions). The version worth comparing to is currently being more accurately redefined by a standardization body in the Federal Republic of Germany.

3) *Reference equivalents* , but determined objectively by some kind of instrumentation. It should be noted that the ‘‘reference loss’’ of a junction circuit is often determined as the dB average over a log(f)-scale.

4) Recommendation P.79. This is the ‘‘youngest’’ standard. The U.K. has the widest experience in its application. From a transmission planner’s point of view it leaves something to be desired, and a possible modification is described in [13].

Of course, to ensure telephone speech loudness quality in international connections it is desirable that Administrations employ methods for loudness rating evaluations which are compatible, or preferably identical. The aim of this exposition is to show that for transmission planning a modified, or amended, version of Recommendation P.79 is compatible with the IEEE, the OREM-B and the original Rec. P.79 standard, as well as with some aspects of the reference equivalent practice. In addition, this amended P.79 algorithm needs much less computation effort. (The principles are given in [13] and in § 5).

For a transmission planner the most important loudness parameters are the send, the receive and the junction loudness ratings. Note that the send and receive loudness ratings for transmission planning purposes *do not* have to relate uniquely to subjective values determined by comparison with some reference telephone system set-up. The important aspect is that the (send + receive + junction) loudness ratings add up to the correct overall loudness rating (OLR), which in turn should have a good correlation with a subjective measure. (But this cannot mean that different countries can use different ratings that subdivide the OLR differently!)

What order of computation accuracy is needed? With regard to the additivity of loudness ratings as well as for setting limits in a national transmission plan, 0.5 dB accuracy would probably be adequate. For translating between different standards, 1.5 dB seems sufficient. (The loudness rating manufacturing tolerances for telephone sets, however, have to be much wider).

6.3 *Basics of the loudness rating methods*

The physiological background to the loudness rating methods is as follows:

The ear functions as a bank of narrow bandpass filters. (About 64 equivalent filters having bandwidths of 50-500 Hz, called ‘‘critical frequency bands’’). In a specific band only, that portion of the sound energy which lies above the hearing threshold is presented to the brain as a stimulus. The brain combines all filter outputs of a complex sound (such as the human voice) into an impression of loudness.

Each filter contributes in proportion to an exponent m | of its output power, m | being in the order of 0.2-0.3 for normal speech levels. For very low levels, near the threshold of hearing, as well as for very high levels, m equals 1, corresponding to power addition. But it is important to note that for normal telephone speech, weaker spectral components contribute more to the total loudness impression than if they were added on a direct power basis. As a matter of fact, they approximately add on a linear dB scale.

A more complete theory of hearing, according to Zwicker, also takes into account certain masking effects between the stimuli from the different frequency bands. For telephone purposes, however, the Zwicker method does not seem to give any better agreement with subjective values. See [11] and [7].

In an active telephone connection the listener's impression of loudness is influenced by his own hearing sensitivity/frequency curve and the talker's speech spectrum. A general loudness rating thus has to consider the statistical average for the human population.

The loudness rating algorithms mentioned can all be written in the following form:

where

L_0, m | and K_i | are constants. The index ''i'' refers to the frequency f_i.

L_i | is the appropriate measured and/or computed electroacoustic loss in dB for send, receive, overall and junction rating respectively.

The coefficients K_i | depend on the ''average'' speech and hearing properties, some average transmission characteristics of a typical circuit, as well as the spacing between the frequencies f_i. Thus the K_i's are in general frequency-dependent with proportionally lower values at the band edges. (An example of how to determine the K_i's is found in [6]). However, the exact form of the K_i variation is not very critical, as will be shown in the following.

A useful insight into the mathematical behaviour of the loudness rating formula can be had from a Taylor series expansion. Put

Equation (6-1b) can now be written as

ignoring higher-order terms. Here

The coefficient a | is small, in the range 0.02 to 0.03 for m | in the range 0.175 to 0.3.

Thus, the exact value of m | is quite uncritical, as will be shown numerically below. As a matter of fact, the second term in equation (6-4) can be almost disregarded if the L_i's deviate only moderately from the average L_m, which is the case for most telephone send and receive characteristics.

This explains why send, receive and junction loudness ratings can be added to get the overall loudness rating, at least as long as no hard band-limiting is included in the frequency range.

Moderate variations in the coefficients K_i | between diferent algorithms can of course be interpreted as small correction terms to be added to the L_i's. Thus, the results from different algorithms can be expected to differ only by some constants, fairly independent of the telephone set characteristics.

Similarly, other corrections involving small frequency-dependence can also be treated as constants added to the loudness ratings (for example earcap leakage, difference between measuring set-ups, etc.).

In practice, the transmission bandwidth of a telephone connection may of course differ, depending on what type of links are included. Discussions of how this can be handled when determining the loudness rating can be found in [13] and in § 5, which propose an amendment to Rec. P.79.

To investigate the properties of various loudness rating algorithms it is useful to make computations for a number of typical telephone set characteristics. Below, seventy-one widely different characteristics have been used to obtain a statistical picture. See Annex B for details.

6.4 *Particulars about some algorithms*

Only the mathematics of the algorithms are dealt with. Differences in the measuring arrangements are not considered here. The statistics refer to computations using the 71 different set characteristics as mentioned above. The result of the computations are given with 0.01 dB precision only to show the differences clearly. This ‘‘accuracy’’ is of course not at all necessary or useful in practice.

6.4.1 *IEEE standard*

The computation range is 0.3 to 3.4 kHz with $m = 0.22$. The K_i-weighting is flat on a log (f)-scale, i.e. all K_i's are equal except the end points which have half the value. (From a physiological point of view the weighting should really taper off slightly at the band edges).

In the calculations presented here, 43 frequency points have been used.

6.4.2 *OREM-B standard*

Measurements of OREM values have traditionally been made with special electroacoustic instruments. Recently, however, FTZ in the Federal Republic of Germany has found it possible to compute OREM-B values according to Equation (6-1) using measured sensitivity curves [14].

The computation range is 0.2 to 4 kHz with $m = 0.3$. The K_i-weighting is flat on a log (f)-scale as for the IEEE method, but for the send and overall loudness ratings the loss of a SFERT filter is added to L_i in Equation (6-1). Fifty-three frequency points are used.

6.4.3 *Rec. P.79 standard*

The computation range most often used is 0.2 to 4 kHz with m = 0.175. The constants L_0 and K_i | are transformed into the so-called W_i-weights which are added to the L_i's. The earcap leakage L_E is included for RLR and OLR.

The W_i's are of course tabulated in Recommendation P.79 and the corresponding K_i's are shown in diagrams in [7]. Fourteen frequency points, spaced 1/3 octave apart, are used.

The Rec. P.79 constants were tailored to make computed loudness ratings agree with the correspondings subjective values obtained by a *specific* CCITT test team some years ago. Therefore, in some respects Rec. P.79 does not quite represent subjective values obtained by ‘‘ordinary’’ people. Rec. P.79 puts too much emphasis on the lower frequencies and the weighting coefficients show some peculiar irregularities. (See [11] and [7] for a discussion.) Also, if a connection contains links of different bandwidths some ambiguity may occur.

When applying Rec. P.79 in practice, computer programs are most often used. Telephone set sensitivity curves and chain matrix data of the individual links are the inputs, and SLR and RLR are computed to an interface terminated by 600 ohms (which, incidentally, may not be the nominal impedance at that point!). JLR is not calculated very often.

6.4.4 *An amended Rec. P.79 standard: P.79A*

Details of this proposal are given in [13].

Eleven frequency points spaced 1/3 octave apart, are used. The computation frequencies start at 0.315 and end at 3.15 kHz, making the range extend virtually from 0.3 to 3.4 kHz.

The K_i's are all equal to 0.1 except for the end points where they are equal to 0.05. This trapezoidal weighting thus takes some account of the physiological facts about speech spectrum and hearing sensitivity curves.

Loudness rating for tandem-connected links of wider bandwidths than 0.3-3.4 kHz is taken care of by the ‘‘loudness-improvement’’ *E* -factor, which is subtracted from OLR.

In the more ‘‘exact’’ version of the amendment, $m = 0.2$. This is here designated ‘‘P.79A1’’.

A simpler approach is to let $m = 0$, i.e. use the weighted loss average according to Equation (6-3). This version is here designated ‘‘P.79A’’.

In Equation (6-1) the constant L_0 is:

for SLR: — 3

for RLR: 12

for OLR: 9

for JLR: 0

When using P.79A1 or P.79A there is much less need for complex computer programs. The LRs of the individual links can be added with good accuracy.

6.4.5 *Dependence on the m-value*

The designation ‘‘*d* ’’ is used to illustrate the change of a loudness rating as a function of the coefficient *m* . The ‘‘norm’’ value of a particular standard corresponds to $d = 0$.

It can be seen from Table 6-1 that the choice of *m* | is very uncritical. It explains why P.79A1 with $m = 0.2$ and P.79A with $m = 0$ are fairly equivalent.

H.T. [T19.19]

TABLE 6-1

Values of d (i.e. changes in LR) as a function of m

(Statistics from 71 telephone set characteristics)

Standard	m	Send		Receive	
		Mean	Standard deviation	Mean	Standard deviation
IEEE	0.175	—0.15	0.05	—0.22	0.02
	0.2	—0.05	0.02	—0.08	0.01
	0.22	— 0.**05**	0.**02**	— 0.**08**	0.**01**
OREM-B	0.175	—0.21	0.13	—0.22	0.11
	0.2	—0.13	0.10	—0.14	0.08
	0.3	— 0.**05**	0.**02**	— 0.**08**	0.**01**
P.79A1	0.02	— 0.33	0.21	— 0.07	0.07
	0.175	— 0.05	0.03	— 0.01	0.01
	0.2	— 0.**05**	0.**02**	— 0.**08**	0.**01**

Table 6-1 [T19.19], p.

6.4.6 *Additivity properties*

An indication of how well a certain algorithm is suited for planning purposes is how closely the sum of send, junction and receive ratings corresponds to the overall rating. The difference between OLR and the sum of SLR + JLR + RLR is denoted as ‘‘*D* ’’.

Of special interest is how links of different bandwidths are treated. In a local, analog network the transmission range can be considered as 0.2 to 4 kHz. In a long-distance network (including international links) one can hardly be assured of transmission outside the range 0.3-3.4 kHz. Modern PCM systems, digital exchanges, etc., may have an effective band of 0.2-3.4 kHz.

The IEEE standard only deals with the ‘‘narrow band’’ 0.3-3.4 kHz.

The amended P.79 standard (P.79A1 and P.79A) uses the same ‘‘narrow band’’ for SLR, RLR and JLR calculations. If the actual transmission band is wider, the sum is diminished by a ‘‘loudness improvement factor’’ *E* to obtain an OLR which has a good correlation with subjective loudness impressions. (See [13] and § 5.)

The unmodified P.79 standard for practical cases uses the range 0.2-4 kHz. Depending on the bandwidths of the links and the choice of interface to which the SLR and RLR calculations refer, some ambiguity can then occur.

In Table 6-2 values of *D* are given and, for reasons of simplicity, the junction is considered to have a flat frequency response over the frequency band considered.

Note the large errors when P.79 is applied to a ‘‘narrow band’’ connection such as can be expected in international calls.

The IEEE standard has the second worst additivity performance. (But it is of course satisfactory in practice.)

H.T. [T20.19]

TABLE 6-2

Values of D = OLR-SLR-RLR; JLR = 0

(Statistics from 71 telephone set characteristics)

Algorithm	Band (kHz)	D (mean)	Standard deviation	D (max.)	D (min.)
IEEE	0.3-3.4	0.84	0.24	1.42	— 0.08
OREM-B	0.2-4.**4**	0.19	0.24	0.62	—0.48
P.79	0.2-4.**4**	—0.48—	0.19	—0.11—	—0.98
P.79	0.2-3.4	—0.12—	0.13	0.17	— 0.56
P.79	0.3-3.4	—1.78—	0.09	—1.60—	—2.09
P.79A1	0.3-3.4	—0.06—	0.20	0.45	—0.70
P.79A	0.3-3.4	0.**06**	0.**20**	0.**45**	{
— 0.**70** }					

Table 6-2 [T20.19], p.

6.5 *Numerical comparisons between loudness ratings of different standards*

6.5.1 *P.79 algorithm*

From a transmission planner’s point of view, the use of the simple loudness rating algorithm P.79A seems attractive. It is then of special interest to compare with results obtained when applying the ‘‘normal’’ P.79 algorithm.

Table 6-3 shows the differences for SLR, RLR and OLR for connections having different bandwidths. (The frequency response is assumed to be flat within the passband, however.)

H.T. [T21.19]
TABLE 6-3
Values of D = LR(P.79)-LR(P.79A)
(Statistics from 71 telephone set characteristics)

LR	Band (kHz)	D (mean)	Standard deviation	D (max.)	D (min.)
SLR	0.2-4.**4**	—1.12	0.53	0.15	—2.61
	0.2-3.4	—0.93	0.55	0.32	—2.47
	0.3-3.4	— 1.0	0.38	1.68	—0.03
RLR	0.2-4.**4**	—0.65	0.46	0.43	— 1.95
	0.2-3.4	—0.46	0.47	0.61	—1.73
	0.3-3.4	— 1.52	0.31	2.06	— 0.55
OLR	0.2-4.**4**	—0.85	0.69	0.58	—2.57
	0.2-3.4	—0.77	0.71	0.72	—2.54
	0.3-3.4	— 0.75	0.54	1.78	—0.59

Table 6-3 [T21.19], p.

It can be seen from Table 6-3 that the P.79 and the P.79A algorithms are reasonably equal to each other, considering the bandwidth ambiguity of the P.79. They seem to give the same numerical values (on the average) for a connection having a slightly narrower effective band than 0.2-3.4 khz but broader than 0.3-3.4 kHz, i.e. a case often to be expected in practice.

As mentioned earlier, the junction loudness rating, JLR is of less importance when using P.79 in practice. As a matter of fact JLR (P.79) can give somewhat misleading results because of the band edge peculiarities of the algorithm as discussed earlier.

JLR values calculated by the P.79A1 and P.79A algorithms are more useful to the network planner for several reasons. The additivity properties are better, and some previous investigations indicate good agreement with subjective measurements of loudness loss ([15]). (As a matter of fact the Swedish Administration has used similar algorithms for 20 years.)

The more ‘‘complete’’ algorithm P.79A1 may be safely assumed to give the closest agreement with subjective measurements of JLR. For the transmission planner it is of interest to compare with:

a) JLR results when using the still simpler algorithm P.79A.

b) Circuit losses as defined by the difference in relative levels (= L_1).

When the frequency response curve is flat all these quantities are of course identical. But typical unloaded subscriber cable introduces a high degree of attenuation distortion in the telephone channel. A number of cases (27) have been investigated, including different cable diameters, d.c. resistance (lengths) and terminations.

For these investigations the cable data were: capacitance 45 nF/km; diameters 0.4, 0.5 and 0.7 mm; lengths corresponding to 300, 600 and 1200 ohms d.c. resistance. The terminations were 600, 900 ohms and a typical complex impedance (200 ohms in series with a parallel combination 820 ohms and 115 nF).

The difference of JLR calculated using two algorithms is presented in Figure 6-1 as a function of the cable attenuation distortion, i.e. the difference between the loss at 4 kHz and the loss at 0.2 kHz. (For the same length of a cable, the complex impedance termination gives the largest distortion. In practice, distortions larger than about 15 dB should be avoided for various reasons.)

As can be seen from Figure 6-1 the P.79A algorithm is sufficiently accurate to be used for JLR calculations, the differences being less than 0.3 dB for a distortion up to 15 dB.

Figure 6-1, p.

The subscriber cable loss as defined by L_1, the difference in relative levels, is simply the (composite) loss at 1 kHz according to the CCITT definition (even for a complex impedance termination). Figure 6-2 shows that the difference to the ''true'' JLR value is always less than 1 dB, and presumably less than 0.5 dB in the majority of practical cases.

Thus the difference in relative levels, L_1, can also be used, with good accuracy, as a measure of the change in loudness rating, JLR. This makes the task easier for the network planner.

Figure 6-2, p.

6.5.2 *IEEE and OREM-B algorithms*

To what degree will it be possible to make simple conversions between P.79A and the IEEE and OREM-B standards? That is, what is the difference

$$D = LR — LR\ (\text{P.79A})\ ? \qquad (6\text{-}6)$$

Of interest are the average D (mean) and the standard deviation for typical telephone set characteristics. Because possible differences in measuring set-ups have not yet been investigated, it is for the moment only relevant to study the standard deviations.

The computation results are presented in Table 6-4. The standard deviations are quite small, indicating that it will indeed be feasible to make simple conversions.

H.T. [T22.19]
TABLE 6-4
Standard deviation of [LR-LR(P.79A)]
(Statistics from 71 telephone set characteristics)

Standard	LR	Band (kHz)	Standard deviation
IEEE	Send Receive Overall	0.3-3.4	0.31 0.1 0.4
OREM-B	Send Receive Overall	0.2-4.**4**	0.52 0.38 0.5

Table 6-4 [T22.19], p.

6.6 *Conclusions*

A proposed amendment, P.79A, to the loudness rating Recommendation P.79 has been investigated and found adequate for transmission planning purposes. (The algorithm P.79A corresponds in principle to taking a weighted dB average over a log (*f*)-scale. See § 6.4.4 and [13].

The algorithm P.79A has been shown to give, with sufficient accuracy, numerically equal values with P.79 in typical transmission planning situations. P.79A can be expected, for good reasons, to agree better with subjective values than P.79.

It also seems possible to make simple conversions between P.79A, IEEE and OREM-B loudness ratings.

P.79A has the best additivity accuracy as well as the most simple form.

Administrations are therefore urged to make some comparative studies using this P.79A algorithm in transmission planning.

7 **Information on the Zwicker loudness rating method as used by the French Administration** (Contribution from the French Administration)

7.1 *Introduction*

The method recommended for the evaluation of the quality of a communication in terms of loudness is that of loudness rating (LR). The subjective determination of these equivalents is described in Recommendation P.78, and the objective determination in Recommendation P.79.

However, other parameters (e.g. R25E) have been used, and no universal formula is available to transform these parameters into LR. Therefore it will be useful to have a description of how both values (e.g. R25E and LR) can be objectively measured for a given equipment.

This Section sets out to describe a method for an objective evaluation of loudness losses (R25 equivalents and loudness ratings) used by the French Administration, as stated in the SG XII/3 Report, in Boglarlelle, May 1987 (TD64 revised).

7.2 *Characteristics of the method*

The computation of the loudness of stationary-type signals using the Zwicker algorithm, when applied to the objective measurement of R25 equivalents and LR, gives results which are in good agreement with results obtained using the corresponding subjective evaluation methods [16].

One specific characteristic of this algorithm is that it can be used to compare loudness between systems whose transmitted frequency bandwidth is not within the limits of 300-3400 Hz.

Adaptations of the Zwicker algorithm to monaural and binaural listening modes respectively are used to evaluate different types of terminals: handset telephones [16], operator headsets [17] and loudspeaker telephones [18].

It is essential to use ‘‘complex’’ voices as defined in Recommendation P.51 to measure nonlinear systems. This algorithm has lead to satisfactory results in the evaluation of hand-free sets [19] when using such input voices.

7.3 *Principle of Zwicker’s algorithm to calculate loudness*

The method is based on the use of method B of ISO 532 Rec. (Zwicker method).

7.3.1 *Essential phenomena considered in the calculation of loudness*

The algorithm establishes a relationship between the stimulus (physical) and the auditory sensation (psychoacoustical). Loudness is composed of three main phenomena which are as follows: critical bands, masking and equal loudness levels.

7.3.1.1 *Critical bands*

In the human ear, wideband sounds seem to be louder than pure or narrow-band sounds with the same acoustic pressure levels. It is also possible to prove that, around a given frequency and for a fixed level of acoustic pressure, loudness remains constant as long as the sound bandwidth does not exceed a given value called the critical band. If sound bandwidth exceeds this value, a distinct increase in loudness can be noted. In this way, the ear divides the domain of audible frequencies into 24 critical bands, within which any excitation is integrated without weighting. Therefore, loudness measurement is based upon spectral sound analysis.

7.3.1.2 *Masking effect*

The masking effect consists of raising a (reference) sound’s threshold level of audibility when transmitting another sound of a (masking) noise with a lower frequency (or higher, but in a weaker proportion). This can be explained via the notion of specific loudness.

7.3.1.2.1 *Specific loudness*

A narrow band of noise or a pure sound, whose spectral energy is concentrated at one specific point of the frequency range, causes a large portion of the basilar membrane (one of the essential auditory organs) to vibrate. This causes not only an excitation of the centre, but also an excitation of the sides which is especially significant in frequency zones above that of the signal frequency. The effect of these side excitations shows itself via the masking effect. The excitations of the centre and the sides contributes to the specific signal loudness.

7.3.1.2.2 *Masked or partially masked loudness*

If a weak sound falls in the highest frequency zone as defined above, it can be masked partially or totally by the side excitations, and therefore does not produce any specific loudness.

7.3.1.3 *Equal loudness levels*

The ear is not equally sensitive to different frequencies; curves of equal loudness levels allow to compare the loudness of sounds produced by sounds of different frequencies once the signal levels have been physically measured. On an ‘‘acoustic pressure level vs. frequency’’ diagram, these curves link the points which correspond to an equal sensation of sound loudness, including those found at the threshold of hearing.

7.3.2 *Global loudness of a complex sound*

Using a spectral analysis in thirds of octaves the Zwicker method [20] is used to calculate the loudness of stationary signals with the following double correction:

— by transforming the pressure level in each third octave band into a specific loudness,

— by a specific loudness summation, weighted by the masking effect.

7.3.3 *Computer measurement of loudness*

This measurement is possible since the acoustic pressure level for each third octave band is known. The FORTRAN program enabling this loudness to be computed is described in [21].

Note — The Zwicker algorithm includes two variants: one for listening in a free field, the second for listening in a diffuse field. Results referenced in [16], [17] made use of the first variant. Both lead to satisfactory values when applied for the determination of R25 and LR.

7.4 *Application of the Zwicker method for measuring the loudness loss (LL): R25 equivalents (R25E) and loudness ratings (LR)*

7.4.1 *Fundamental principle of the objective LL measuring method*

The principles on which the following instrumental method are based are similar to the subjective methods described in Figures 7-1 and 7-2 for determining the R25 equivalents and LR. In this method:

a) The speech signals are replaced by an artificial acoustic voice, the spectral characteristics of which are given in Recommendation P.51.

b) The reference parameters and signals are calculated on the basis of the nominal efficiency characteristics, as a function of the frequency of the NOSFER and IRS defined in P.42 *(Red Book)* and P.48. These are:

— the artificial electric voices resulting from the transmission of acoustic artificial voice via reference transmission systems,

— the NOSFER reference loudness (RL),

— the loss x_2 as a result of comparing and equalizing the loudness of NOSFER and IRS paths.

Third octave bands are a good approximation of the critical bands, provided that bands lower than 280 Hz are appropriately grouped together.

c) The values of ‘‘*LE* ’’ relative to acoustic leakage are used as artificial ear/real ear correcting terms.

d) Operator evaluation of sound loudness is replaced by a calculation of the loudness of stationary noise intercepted by a standardized artificial ear, and is performed according to Zwicker’s algorithm.

Figure 7-1, p.

Figure 7-2, p.

7.4.2 *Characteristics of reference signals and parameters*

The reference signals and parameters which objectively characterize speech communication in Figures 7-1 and 7-2 are defined hereafter.

Note — Whether it is a question of human or artificial mouths and ears, the definition of mouth and ear reference points (MRP and ERP) does not change (Annex A of Recommendation P.64) and the standardized speaking positions are identical.

— *Acoustic artificial voice:* defined at the MRP. For spectral characteristics, see Table 2/P.51.

— *Electrical artificial voices:* these voices substitute, at points JS in Figures 7-1 and 7-2, for the human voice/NOSFER or IRS systems. For spectral characteristics see Tables 7-1 and 7-2 (columns N_T and $N_S$respectively).

— *Reference loudness (RL):* loudness of the acoustic signal at the e.r.p. of ‘‘path 0’’, when the acoustic artificial voice is applied to the MRP.

RL = 21.1 sones

— x_2: loss calculated according to the flowchart in Figure 7-4 to give equal loudness for paths 0 and 2 (Figure 7-2).

$$x_2 = 21.5 \text{ dB}$$

— *Acoustic leakage ‘‘LE’’:* defined in two cases:

i) for the telephone set receiver (Table 4/P.79)

ii) for the NOSFER receiver (Table 7-3, LE_R).

H.T. [T23.19]
TABLE 7-1
Electrical artificial voice of the NOSFER
(output of the NOSFER sending system)

Frequency (Hz)	*N (dBV)*	*Frequency (Hz)*	*N (dBV)*
100	*—29.7*	*1000*	*—20.3*
125	*—24.7*	*1250*	*—22.1*
160	*—21.4*	*1600*	*—24.3*
200	*—19.2*	*2000*	*—26.0*
250	*—18.6*	*2500*	*—27.8*
315	*—18.4*	*3150*	*—28.1*
400	*—18.7*	*4000*	*—29.9*
500	*—18.7*	*5000*	*—34.8*
630	*—18.8*	*6300*	*—42.7*
800	*—19.4*	*8000*	*—46.4*

Table 7-1 [T23.19], p.

H.T. [T24.19]
TABLE 7-2
Electrical artificial voice of the IRS
(output of the IRS sending system)

Frequency (Hz)	*N (dBV)*	*Frequency (Hz)*	*N (dBV)*
100	*—68.9*	*1000*	*—22.6*
125	*—55.3*	*1250*	*—23.3*
160	*—42.0*	*1600*	*—23.6*
200	*—33.6*	*2000*	*—24.8*
250	*—27.7*	*2500*	*—25.1*
315	*—23.8*	*3150*	*—26.8*
400	*—21.7*	*4000*	*—67.0*
500	*—21.0*	*5000*	*—82.8*
630	*—21.5*	*6300*	*—104.5*
800	*—21.9*	*8000*	*—120.5*

Table 7-2 [T24.19], p.

H.T. [T25.19]
TABLE 7-3
NOSFER receiver acoustical leakage

Frequency (Hz)	*LE (dB)*	*Frequency (Hz)*	*LE (dB)*
100	— 0.9	1000	—4.5
125	— 0.2	1250	—3.9
160	—0.6	1600	—4.6
200	—1.6	2000	—3.3
250	—2.9	2500	—3.2
315	—4.2	3150	—3.3
400	—5.3	4000	—3.7
500	—5.4	5000	—2.9
630	—4.9	6300	—0.8
800	—4.6	8000	—0.8

Table 7-3 [T25.19], p.

7.4.3 *Loudness loss computation*

Generally, the measurement consists in comparing and setting the reference loudness (RL) equal to the loudness of the various paths being studied (Figures 7-1 and 7-2). However, considering the structural modification of these paths (see § 7.4.2), the analogy between the subjective and the objective method is only possible if the signals which characterize these paths have been corrected (β_i terms of Figures 7-3 and 7-4: acoustical leakage, nominal sensitivity/frequency of the reference receiving systems) before calculating their loudness and comparing them to the reference.

The R25 equivalents and LR are therefore calculated according to the flowcharts in Figures 7-3 and 7-4.

Figure 7-3, p.

Figure 7-4, p.

7.5 *General structure of the CERF apparatus of the French Administration*

The diagram in Figure 7-5 shows how the main elements of the measuring device performing the operation described above are organized. [22] gives a detailed description of the functions and features of the device.

Figure 7-5, p.

8 Information on the OREM-B loudness loss method as used by the Administration of the Federal Republic of Germany (Contribution by the Administration of the Federal Republic of Germany)

8.1 *Definition*

Within the area of the Deutsche Bundespost, measurements of loudness ratings are performed according to DIN 44013 ''Objective Reference Equivalent Measuring Device OREM-B, Configuration and Application.''

8.1.1 *OREM-B loudness related ratings, BD*

By definition, the loudness BD is zero if a sound pressure of 1.6 Pa is reached at the SFERT microphone in the Braun ear at a sound pressure of 1.07 Pa under the measurement conditions specified in DIN 44013.

8.1.2 *OREM-B send loudness, SBD*

The send loudness determined by operating the test item (e.g. a telephone set together with the feeding bridge, possibly also with connected lines and other equipment) as an electric transmitter and by comparing the voltage measured at a 600 ohm terminating impedance with the reference voltage.

By definition, the ‘‘SBD’’ is zero if the output voltage at the SFERT microphone in the presence of a 1.07 Pa sound pressure is 285 mV (see Figure 8-1).

Figure 8-1, p.

8.1.3 *OREM-B receive loudness, EBD*

The receive loudness determined by operating the test item (e.g. a telephone set together with the feeding bridge, possibly also with connected lines and other equipment) as an electric receiver and by comparing the sound pressure measured in the Braun ear with the reference sound pressure.

By definition, the ‘‘EBD’’ is zero if the sound pressure measured at an open-circuit voltage of the transmitter of 570 mV (internal resistance: 600 ohms) is 1.6 Pa (see Figure 8-1).

8.1.4 *OREM-B overall loudness, OBD*

(Overall loudness (OBD) of a telephone connection): The reference equivalent determined by comparing a complete telephone connection, possibily together with interposed lines and other equipment, with the OREM-B reference transmitter and receiver (see Figure 8-1).

8.1.5 *OREM-B sidetone loudness, RBD*

The sidetone loudness determined by comparing — in transmissions from the microphone to the receiver capsule of the same test item (e.g. a telephone set with a specific terminating impedance) the sound pressure of the receiver with the reference sound pressure.

By definition, it is zero if the sound pressure measured in the Braun ear is 1.6 Pa in the presence of a sound pressure of 1.07 Pa at the SFERT microphone.

8.2 *Measurement conditions deviating from Rec. P.64*

— Instead of the handset position according to Annex A of Rec. P.76 [the loudness rating guard-ring position (LRGP)], a position according to Rec. P.72 [reference equivalent speaking position (RESP) *(Red Book)*] is used.

— Instead of the IEC coupler, a Braun coupler is used.

— Use is made of an artificial mouth according to Rec. P.51.

— Calibration of the artificial mouth is not performed under free-field conditions but with the aid of the SFERT baffle. The sound pressure build-up in the SFERT baffle is compensated by an adequate filter in the generator section. At the diaphragm of the microphone in the SFERT baffle (see Figure 8-2), spaced 43.5 mm apart from the lip plane, the sound pressure is set to 1.07 Pa (sound pressure level: 94.6 dB). Between 200 Hz and 4000 Hz, the sound pressure should be as frequency-independent as possible. In the process, the SFERT filter is activated.

— Via a regulation loop, the sound pressure is kept constant at the calibration value (independently of the test item).

Figure 8-2, p.

8.3 *Algorithm*

The successive voltages U_1, U_2. | | U_n | of the swept sinusoidal signal are added according to the following law:

for t_i | approching 0:

The exponent m | is 0.6.

The static transient time of the indicator is 3.5 s.

The frequency sweep 200 . | | 4000 . | | 200 Hz is logarithmic with time, with a complete sweep cycle per second.

ANNEX A

(to Supplement 19 — ref. to § 5.3)

E-factor coefficients

The attenuation values L_i | are given for the ‘‘wideband’’ f_1 . | | f_N. The ‘‘wideband’’ LR (W) is computed using the algorithm:

For shortness we use the notation:

The ‘‘common’’ band LR is computed in the narrower range:

According to the definition of the K_i-coefficients we have:

The relationship between the two algorithms is defined to be as follows:

For a strictly band-limited system, i.e. one for which L_1 . | | $L_{N\backslash d1}$ = ∞, we let:

and further we set:

Thus, we get:

and

We will use the following notation:

In the general case we have:

which results in

As the terms in the sum σ" ‘ in Equation (A-11) are small, one can make a series expansion. Thus:

where

The last term in Equation (A-12) is designated as the loudness improvement, the *E* -factor.

In the actual case the ‘‘wideband’’ can be taken to encompass the range f_1 = 200 Hz to $f_{1\backslash d4}$ = 4000 Hz and the ‘‘common’’ band f_3 = 315 Hz to $f_{1\backslash d3}$ = 3150 Hz. The ‘‘band edge’’ frequencies are 200, 250 and 4000 Hz.

The coefficients C_i | have been computed for some LR algorithms under discussion using the K_i-values for OLR as given in Table A-1. (Details of the algorithms are given in [11] and [7] as well as the method used for converting W_i-weights to K_i-weights.) The C_i-values are presented in Table A-2.

The P.79 algorithm or its smoothed version P.79/S are not suitable for band edge performance, analysis as their frequency weighting has been shown to be less correct (too much emphasis on the lower frequencies [7].)

It is apparent from Table A-2 that the C_i-coefficients from the three algorithms do not differ very much. As the human speech and hearing characteristics at the band edges can be expected to vary rather much, the actual values of the C_i’s cannot be critical. Therefore, it is reasonable to use the ‘‘rounded-off’’ values:

and to set m = 0.2.

Which algorithm should be used when computing the ‘‘common’’-band LR? As shown in [11] and [7], there are several algorithms which correlate about equally well with subjective measurements. The simplest one is the algorithm ‘‘*C* ’’ which was therefore chosen.

H.T. [T26.19]
TABLE A-1

Algorithm	*m*	*K*		
		0.2 kHz	*0.25 kHz*	*4 kHz*
P.XXE	*0.225*	*0.0227*	*0.0389*	*0.0292*
CH	*0.2*	*0.0306*	*0.0439*	*0.0324*
B	*0.2*	*0.031*	*0.042*	*0.042*
P.79/S	*0.175*	*0.0536*	*0.0765*	*0.0243*

Table A-1 [T26.19], p.

H.T. [T27.19]
TABLE A-2

Algorithm	*C*			*{*
	0.2 kHz	*0.25 kHz*	*4 kHz*	
P.XXE	*0.48*	*0.83*	*0.62*	*1.93*
CH	*0.74*	*1.06*	*0.79*	*2.59*
B	*0.76*	*1.03*	*1.03*	*2.82*
Mean	*0.66*	*0.97*	*0.81*	*2.45*

Table A-2 [T27.19], p.

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ANNEX B

(to Supplement 19 — ref. to § 6.3)

Seventy-one telephone set characteristics were obtained of which:

a) thirteen from CCITT COM XII-No. 164 (1977-1980), and

b) fifty-eight from Barnes in a private communication.

The statistics of the send and receive sensitivity curves are shown in Figures B-1 and B-2. The curves were normalized by subtracting the ‘‘average’’ sensitivity computed by Equation (6-1b).

Figure B-1, p.

Figure B-1, p.

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