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STANDARDIZATION SECTOR
OF ITU

TELEPHONE TRANSMISSION QUALITY

VOCABULARY AND EFFECTS OF TRANSMISSION PARAMETERS ON CUSTOMER OPINION OF TRANSMISSION QUALITY AND THEIR ASSESSMENT

SUBJECTIVE EFFECTS OF DIRECT CROSSTALK; THRESHOLDS OF AUDIBILITY AND INTELLIGIBILITY

ITU-T Recommendation P.16

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation P.16 was published in Volume V of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation P.16

SUBJECTIVE EFFECTS OF DIRECT CROSSTALK;
THRESHOLDS OF AUDIBILITY AND INTELLIGIBILITY

(Geneva, 1972; amended at Geneva, 1976, 1980;
Malaga-Torremolinos, 1984; Melbourne, 1988)

1 Factors which affect the crosstalk threshold

The degree of audibility and intelligibility of a crosstalk signal depends on a large number of factors.

The main factors influencing the intelligibility of the vocal crosstalk signal are listed below.

1.1 *Quality of transmission of telephone apparatus*

The sending and receiving loudness ratings are decisive factors. The same is true of the sidetone rating when room noise is present. The use of modern telephone apparatus with smooth frequency response curves is assumed.

1.2 *Circuit noise*

The circuit noise on the connection of the disturbed call must be taken into account. The noise level is measured by a psophometer equipped with a weighting network for telephone circuits, as described in Recommendation O.41.

1.3 *Room noise*

Room noise affects the ear directly through earcap leakage between the ear and the receiver and indirectly by sidetone. Sidetone also depends on operating conditions. Unlike circuit noise, the effect of room noise can be reduced to some extent by the user of the telephone. For this reason, and to allow for unfavourable cases, measurements on the audibility of crosstalk have been made with slight room noise as well as with negligible room noise. Because the audibility threshold is very sensitive to masking effects, “negligible” room noise means a noise level well below 10 dBA. The relatively low noise level of 40 dBA has a very marked masking effect and may therefore serve as an example of “slight” room noise.

1.4 *Telephone set noise*

In addition to the masking effects on crosstalk by circuit noise and room noise, the internal noise of the telephone set in the disturbed connection has to be considered. In modern telephone sets this noise is generated in the electronic circuitry (amplifiers, etc.) while in older sets the origin is noise from the carbon microphone. The internal noise can be expressed and treated as an equivalent circuit noise.

1.5 *Conversation on the disturbed connection*

During active speech on the disturbed connection, practical levels of crosstalk are inaudible. However, before the conversation starts or during long pauses in the conversation, it is possible for crosstalk to be heard and perhaps understood. In general, it would be unwise to plan on the basis that the disturbed connection is always active; accordingly, the information given in this Recommendation assumes no conversation on the disturbed connection.

1.6 *Crosstalk coupling*

The intelligibility of a vocal crosstalk signal depends largely on the nature of the crosstalk coupling, which is generally a function of frequency.

The loudness rating of the crosstalk transmission path – from the speech signal present on the disturbing line to the subscriber's set subject to the disturbance – can be divided into the loudness loss of the crosstalk path from the disturbing to the disturbed line and the receive loudness rating of the disturbed subscriber's set. Figure 1/P.16 illustrates this subdivision.

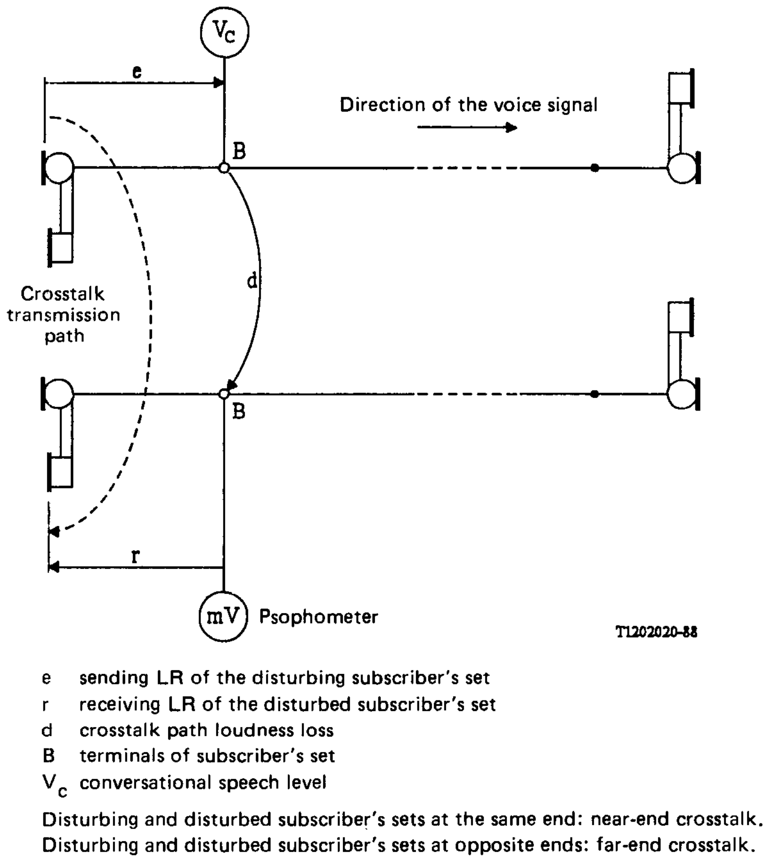


FIGURE 1/P.16

Subdivision of crosstalk transmission path

For a given speech level V_c, the intelligibility of the crosstalk signal depends on the loudness rating $d + r$. In Recommendation G.111, § A.4.4.4, the crosstalk receive loudness rating is defined as:

$$XRLR = RLR(set) + L_x$$

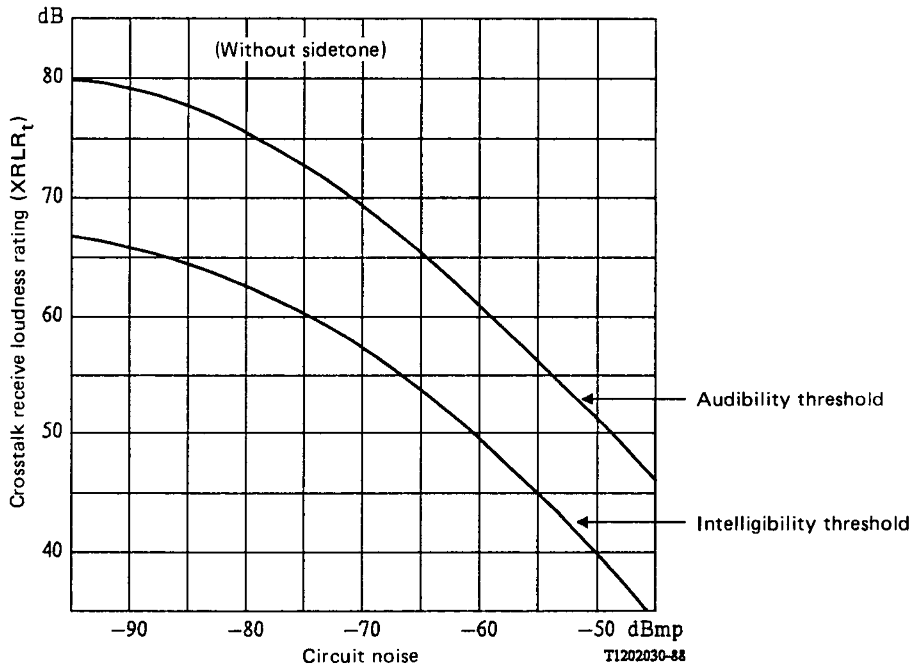
where *RLR*(*set*) refers to the disturbed telephone set.

The crosstalk loudness L_x is computed as a loudness rating but with the exponent m = 1, which is valid near the audibility threshold.

In the absence of further information, the value of L_x may be approximately taken as the attenuation measured or calculated at a frequency of 1020 Hz.

2 Median listener threshold of the audibility and intelligibility of vocal crosstalk

The curves in Figure 2/P.16 represent the crosstalk receive loudness rating corresponding to the threshold of audibility and intelligibility ($XRLR_t$) as a function of circuit noise. For planning purposes, it is recommended that room noise be regarded as negligible, which represents the most unfavourable condition.



Note 1 – The circuit noise is referred to the terminals of the subscriber's set. Room noise is assumed to be negligible.

Note 2 – The vocal level on the disturbing line is assumed to be –18 dBV active speech level.

FIGURE 2/P.16

Threshold value of crosstalk receive loudness rating as a function of circuit noise

The criterion for the threshold of audibility is that the presence of a speech signal is only just detectable but that no part of the speech can be understood. The criterion for the threshold of intelligibility is that single words or phrases can sometimes be understood while listening to a conversation.

The threshold curves represent median values for the two criteria such that in each case 50% of subscriber's opinions are respectively above and below the particular curve. The standard deviation for listeners has been observed to lie in the range 4 to 6 dB and a value of 5 dB is recommended for planning purposes. Typical response curves for a large sample of listeners for the threshold criteria are shown in Figure 3/P.16 (no circuit noise). The difference in XRLR between the two curves is about 12 dB.

The results of the original experiments (from which the curves in Figure 2/P.16 were drawn) were expressed in terms of speech level (e.g. in Volume Units (VU)) and on that basis showed a satisfactory degree of coherence.

However, earlier versions of Recommendation P.16 were based on the assumption that there is a fixed relationship between the sending loudness rating and the speech level on the line. This assumption required a correction in the range of 11 dB and is therefore not justified. Furthermore, speech levels expressed in Volume Units appear to differ systematically as measured in different countries on identical speech samples. Therefore, a fixed speech level on the disturbing line is assumed, independent of the send loudness rating (SLR) of that circuit.

The thresholds given in Figure 2/P.16 are based on the assumption that the speech level V_c under normal conversational conditions is –18 dBV active speech level (measured according to Recommendation P.56) at the terminal of the disturbing telephone set. This value is the estimated average of the conversational level in many countries at the send end of a connection with fairly high overall loudness rating [between the optimum and the maximum permitted (OLR)].

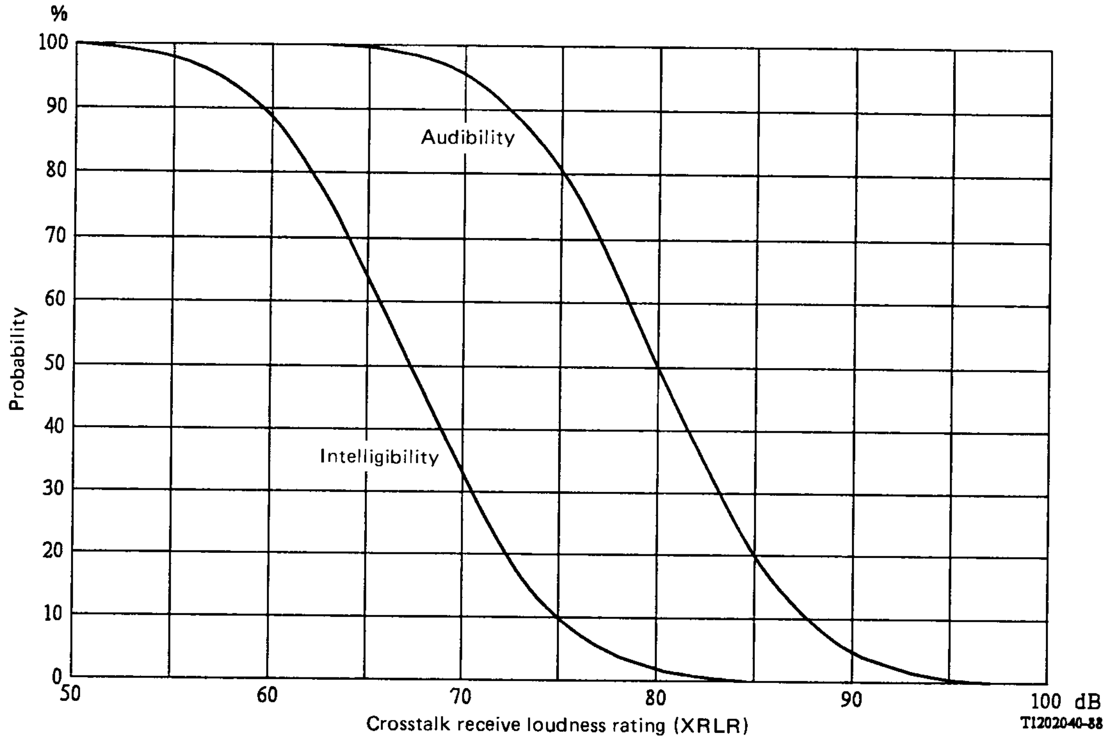


FIGURE 3/P.16

Listener distribution of crosstalk receive loudness rating required for different threshold definitions

The standard deviation of talking levels is fairly high. For calculation purposes a value of σ = 5 dB should be used.

To calculate the threshold value for a speech level different from –18 dBV, the $XRLR_t$ value should be corrected by the amount of the difference, with its sigh (higher levels require higher XRLR values, and vice versa).

The value $XRLR_t$ is the sum of the crosstalk path loudness loss and the receiving loudness loss on the disturbed line. In order to obtain the loudness loss of the crosstalk path, L_x, for a particular threshold value, the RLR(set) value has to be subtracted.

In general, for any speech level and receiving loudness rating, L_x is obtained from Figure 2/P.16 as:

$$L_x = XRLR_t - RLR(set) + (18 + V_c)$$

3 Effects of room noise

Room noise reaches the listener's ear both by leakage under the earcap of the telephone handset and by the sidetone path. For a given sidetone the room noise can be converted to an equivalent circuit noise by means of a transmission model such as described in Supplement No. 3. A family of conversion curves with sidetone loss as parameter is found in Figure 2 of this Supplement.

As an example, with a fairly high sidetone loss (the same as used in the previous version of Recommendation P.16) a level of 40 dBA room noise is equivalent to a circuit noise level of –85 dBmp. This noise level reduces the threshold XRLR value by about 8 dB. An additional reduction will in most cases be caused by earcap leakage.

However, the importance of this effect cannot be generally predicted, since it depends both on the shape of the earcap and on user habits.

4 Crosstalk probability

While the curves in Figure 2/P.16 present the median values for various noise conditions, the curves ub Figure 3/P.16 represent the probability of audible or intelligible crosstalk, in percent, for the negligible noise condition. Similar probability curves can be derived from the median values for any circuit noise condition by the use of cumulative normal distributions with a standard deviation of 6 dB.

In a more general case, the talker variance should also be added. The mean speech level used in the calculations may be chosen to be lower than the relatively high level assumed in Figure 2/P.16, e.g. –20 dBV, which is closer to the average level in the network. An example of such an overall probability calculation is given in Annex A.

The threshold values of crosstalk loudness rating given in this Recommendation can be used in different ways. One possible interpretation is to require all normal telephone connections (i.e. faulty connections excluded) to have crosstalk conditions between the two threshold criteria. This means that, on the one hand, there is no point in requiring a higher crosstalk attenuation than the one corresponding to the audibility threshold and, on the other hand, that the intelligibility threshold should not be exceeded.

Another interpretation is to set the requirement so that there is a given small probability (e.g. 5%) that intelligible crosstalk can be encountered with negligible room noise and with the lowest circuit noise level found in the network. In practice, noise conditions are more favourable in the sense that crosstalk quite often is masked by room and circuit noise to the extent of becoming inaudible. For the average of all connections the risk of intelligible crosstalk will therefore be much smaller than the given percentage for the most unfavourable condition.

Crosstalk requirements may not necessarily be the same for all parts of the network. Although the maintenance of telephone secrecy is primordial, the subscriber is more likely to make a severe judgement on crosstalk in a local call taking place in his immediate environment and in which indiscretion due to crosstalk may have unfortunate social consequences. The problem of “social crosstalk” is dealt with in [1].

In practice, simultaneity of speaking on the disturbing line and listening on the disturbed line (during conversation pauses) is not present in all cases. Information concerning this topic and showing how ti calculate the probabilities concerned will be found in [2].

As guidelines, the probabilities of subscribers encountering potentially intelligible crosstalk should not be worse (i.e. higher) than the following:

– own exchange calls: 1 in 1000,

– other calls: 1 in 100.

Note – The fundamentals of calculating crosstalk probability in general are considered in Recommendation G.105.

ANNEX A

(to Recommendation P.16)

Example of probability calculation

The probability of understanding single words of a conversation overheard by crosstalk may be calculated for a listener chosen at random from a population of subscribers. The result of such a calculation can be used as a basis for establishing rules for, inter alia, the minimum required crosstalk attenuation between subscriber lines in a national network.

In order to demonstrate the method of using the information given in this Recommendation to calculate the probability of encountering (intelligible) crosstalk, the following assumptions may be made:

Mean speech level V_c = –20 dBV;

Receive loudness rating of telephone sets $RLR(set)$ = –6 dB;

No room or circuit noise;

Standard deviation of talking levels σ_T = 5 dB;

Standard deviation of listener response distribution σ_L = 6 dB;

Standard deviation of *RLR*(*set*) $\sigma_S = 1$ dB.

The threshold value for crosstalk intelligibility without noise, taken from Figure 2/P.16 is $XRLR_t = 67$ dB.

According to the formula at the end of § 2 and with the given assumptions, the required median crosstalk path loudness loss becomes:

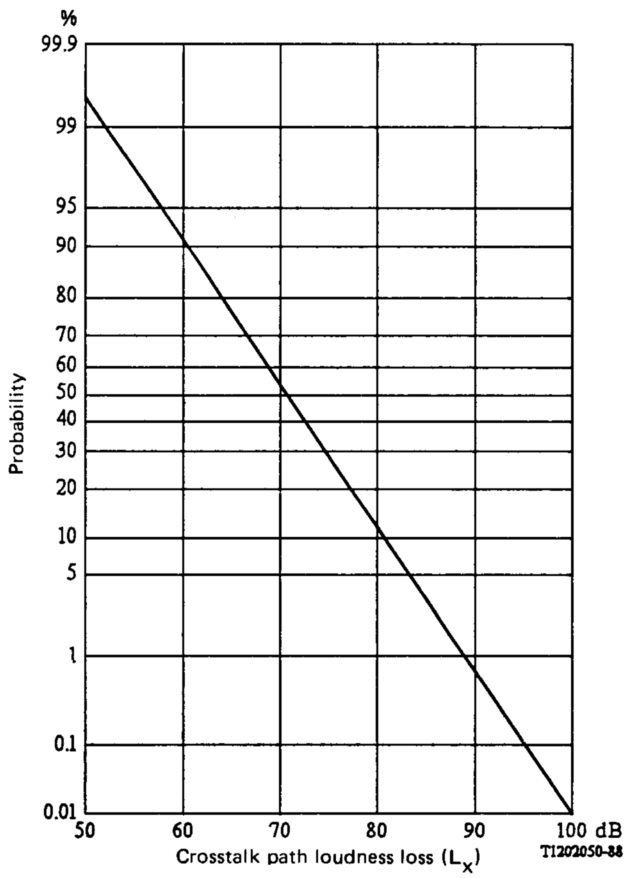
$$L_x = 67 + 6 - 2 = 71 \text{ dB}.$$

The total standard deviation of the probability function is:

$$\sqrt{\sigma_T^2 + \sigma_L^2 + \sigma_S^2} = 7.87 \text{ dB}$$

With these values of L_x and σ, a cumulative normal distribution function as in Figure A-1/P.16 can be drawn. The function indicates the probability that a listener can understand single words if crosstalk for a specific value of the crosstalk path loudness loss. For example, for $L_x = 75$ the probability is 30%. On the other hand, to obtain only 5% probability a crosstalk path loudness loss of 84 dB would be necessary. For 1% probability, 89 dB would be required, as well as 95 dB for 0.1% probability.

This calculation was based on some typical values of speech level and receiving sensitivity under noise-free conditions. Similar calculations can easily be made with other data, also including the effects of noise. For a realistic estimation of the probability of intelligible crosstalk for subscribers in general, some statistical distribution of circuit noise (and possibly of room noise at the subscriber's locations) will have to be assumed.



V_c mean = –20 dBV; RLR (set) = –6 dB; standard deviation = 7.9 dB

FIGURE A-1/P.16

Probability of understanding single words of an overheard conversation as a function of the (weighted) crosstalk path loudness loss L_x

References

[1] WILLIAMS (H.), SILOCOCK (W. W.), SIBBALD (D.): Social crosstalk in the local area network, *El. Comm.*, Vol. 49, No. 4, London, 1974.

[2] LAPSA (P. M.): Calculation of multidisturber crosstalk probabilities, *BSTJ*, Vol. 55, No. 7, New York, 1976.