INTERNATIONAL TELECOMMUNICATION UNION

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TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.126

(03/93)

TRANSMISSION SYSTEMS AND MEDIA

GENERAL CHARACTERISTICS OF NATIONAL SYSTEMS FORMING PART OF INTERNATIONAL CONNECTIONS

LISTENER ECHO IN TELEPHONE NETWORKS

ITU-T Recommendation G.126

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.126 was revised by the ITU-T Study Group XII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

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LISTENER ECHO IN TELEPHONE NETWORKS

(Helsinki, 1993)

1 Introduction and scope

A telephone connection between two subscribers in telephone networks usually contains one or more 2-4-2-wire loops (further referred to as 4-wire loop), as the connection may encounter a mixture of 2- and 4-wire analogue and digital switching and transmission systems, including PBXs. Signal reflections may occur due to the impedance mismatch at both hybrids that terminate a 4-wire loop. A portion of the main signal will thus be reflected at the far end of the 4-wire loop, return to the near end and be reflected again. Therefore the reflected signal will finally arrive at the listener's end some time later than the original signal. The delayed signal is called listener echo.

Listener echo signals can:

– lead to objectionable "hollowness" in voice transmissions; and

– impair the bit error ratio of voice-band data transmissions.

The effect of listener echo on transmission performance can be characterized by the additional loss and additional delay in the listener echo path relative to the direct signal path. The minimum value of the additional listener echo path loss over the frequency band involved provides a margin against singing distortion. Recommendation G.122 provides guidance on the influence of national networks on stability and talker echo in international connections. This Recommendation provides planning guidance for listener echo in telephone networks with the aim of obtaining satisfactory speech and voice-band data transmission performance.

2 Definitions

For the purpose of this Recommendaition, the following definitions apply:

2.1 listener echo (receive end echo): echo produced by double reflected signals and disturbing the listener, receiving voice-band data equipment, etc.

NOTES

1 The term “received end echo” is a term preferred by some Administrations.

2 With small delay against the wanted signal (less than about 3 ms) listener echo may cause hollowness in telephony. In transmission of voice-band data signals, listener echo may cause bit errors and, in any case, reduces the margin against other disturbances.

2.2 listener echo loss (receive echo loss): degree of attenuation of the double reflected signal with respect to the wanted signal. In terms of the absolute losses of both signals, the listener echo loss is (see Figure 1/G.100): LE = L_2 - L_1.

NOTE – For practical purposes the listener echo loss is equal to the open-loop loss (valid if the latter exceeds 8 dB). The listener echo loss characterizes the degree of disturbance by hollowness, as well as the disturbing effect on voice-band data modem receivers.

2.3 hollowness: distortion in telephony caused by double reflected signals and subjectively perceived as a “hollow sound”, i.e. as if the talker would speak into some hollow vessel.

NOTE – Hollowness is to be distinguished from listener echo.

2.4 open-loop loss (OLL): in a loop formed by a 4-wire circuit (or a cascade connection of two or more 4-wire circuits) and terminated by 2-wire ends (i.e. having “4-wire terminating sets”, or hybrids, at both ends), the loss measured by breaking the loop at some point, injecting a signal and measuring the loss incurred in traversing the open loop. All impedance conditions should be preserved while making the measurement. See Figure 2/G.100.

NOTES

1 In practice the OLL is equal to the listener echo loss.

2 The OLL is also equal to the sum of the two semi-loop losses associated with a loop.

2.5 path a-t-b (transmission loss of ...); semi-loop loss: the transmission loss between the points “a” and “b” of the 4-wire termination (as defined at the virtual switching points) independent of whether there exists or not a physical point “t”.

2.5.1 Possible alternative to the definition in 2.5

Semi-loop loss

In an arrangement comprising a 4-wire circuit (or a cascade connection of several 4-wire circuits) with unwanted coupling between the go and return direction at the ends of the circuit - usually via a 4-wire terminating set, or via acoustical coupling - the loss measured between the input and output. See Figure 3/G.100.

NOTES

1 The semi-loop loss is an important quantity in determining echo balance return loss, echo loss, listener echo loss (see also open-loop loss).

2 Distinction may be made between the semi-loop loss of a given piece of equipment and the semi-loop loss of a national system. The latter is measured at equi-level points in an ISC which serves as a national gateway exchange.

2.6 singing margin (SM): the minimum listener echo loss in dB over the frequency band involved.

2.7 round-trip delay (DL): the delay in ms around the closed 4-wire loop, determined primarily by the two-way delay of the 4-wire transmission path, which is equal to listener echo path delay.

2.8 weighted listener echo path loss (WEPL): WEPL is the weighted mean value of listener echo loss expressed by the following equation:

$$\text{WEPL} = -20 \log_{10} \frac{1}{3200} \int_{200}^{3400} 10^{-\frac{\text{EPL}(f)}{20}} \, df$$

Where

EPL (*f*) = magnitude of listener echo loss in dB at the frequency *f*.

This concept was originally used in North America, in the transmission rating model, which can be used to derive the subjectively equivalent effects of listener echo on voice transmission performance regardless of the frequency response of the listener echo loss in the connection.

3 Effect of listener echo

3.1 General

Figure 1 shows a connection with one 4-wire loop. The loss of the direct signal path is assumed to be *S* dB, whereas the loss along the path of the double-reflected signal is *L* dB. The listener echo loss (LE) is then (L–S) dB. It can be seen from Figure 1 that if signals are reflected twice only, the listener echo loss LE is equal to the loss around the 4-wire loop (Open-Loop Loss, OLL), as the other path losses are incurred equally by the direct and the reflected signals. Obviously, the additional delay of signals reflected twice is also equal to that around the 4-wire loop (round trip delay, DL), primarily determined by the two-way delay of the 4-wire transmission path.

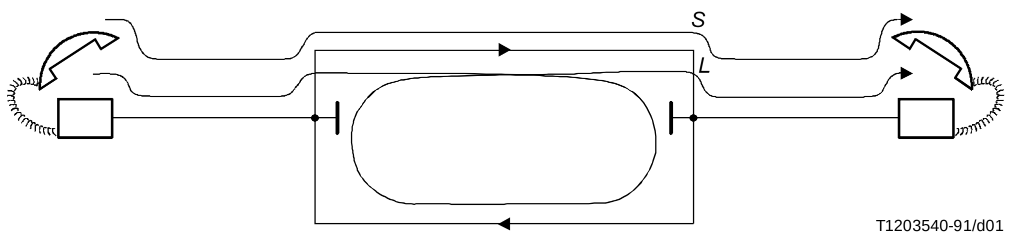

FIGURE 1/G.126

Listener echo

The loss around the 4-wire loop can be measured by breaking the loop at some point, injecting a signal from one end and measuring the loss incurred in traversing the open loop at the other end. All impedance conditions of the closed loop at the 2-wire ends should be preserved while making the measurement. The measured quantity is the Open Loop Loss (OLL), which is also equal to the sum of the two semi-loop losses (SLL) associated with the 4-wire loop. For practical purposes, semi-loop measurements may be more easily carried out, especially in the case of 4-wire exchanges with 2-wire circuit terminations, since it is sometimes difficult to maintain a connection through a 4-wire exchange and interrupt one direction of transmission. The definition of SLL and its measurement are illustrated in Figure 3/G.100.

3.2 Effect on voice transmission

The effect of listener echo on voice transmission performance will be dependent on the open loop loss and round-trip delay of 4-wire loops. It should be noted that usually the listener echo will consist of a series of signals reflected two times, four times, etc. and hence LE and OLL are in principle not equal. In practice however, LE and OLL may be taken as equal when OLL exceeds 8 dB.

The results of some experiments show that the effect of listener echo on voice transmission performance will be negligible when OLL is greater than 10 dB with the round-trip delay less than 10 ms [1].

Considering that the listener echo loss (or OLL) is normally shaped with frequencies and its minimum value (Singing Margin, SM) often occurs at the edge of the voice-frequency band, the minimum OLL can be taken as a margin against instability but does not provide the optimal measure for assessing the subjective quality of a near-singing connection [2]. The experiment results reported in Supplement No. 3 of CCITT *Blue Book* Volume V suggest that the weighted value of OLL over the voice-frequency band is more appropriate for evaluating the effect of listener echo on voice transmission performance. Based on the transmission rating model described in Supplement No. 3 of Volume V, the transmission quality index may be used to evaluate the effect of listener echo combined with other impairment factors on subjective speech transmission performance in connections.

3.3 Effect on voice-band data transmission

Listener echo causes ripples in the frequency response of the received voice-band data signal and impairs its bit error ratio. In order to obtain satisfactory transmission performance, the value of OLL in the band 500 to 2500 Hz should be higher than that for voice transmission in the band 300 - 3400 Hz due to the strict performance requirement of voice-band data transmission. In addition, the round-trip delay factor may be disregarded when characterizing the effect of listener echo on voice-band data transmission performance, since voice-band data error performance does not appear to be related to the delay. The results of some experiments show that the OLL required for satisfactory voice-band data transmission mainly depends on the data transmission speed, but sometimes also on the type of modems [3].

3.4 Effect of listener echo in a connection with multiple 4-wire loops

If there is more than one 4-wire loop in a connection, several reflected signals will accumulate at the receiving end as shown in Figure 2 (for the sake of simplicity, higher order reflections are not shown).

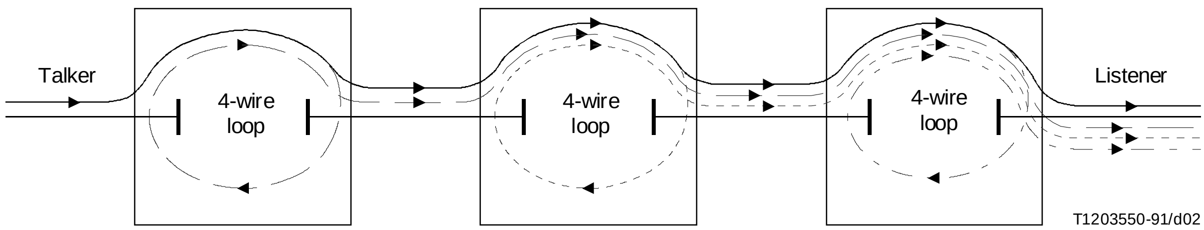

FIGURE 2/G.126

Signal reflections in a connection with multiple 4-wire loops

In a connection with multiple 4-wire loops, the effect of listener echo on transmission performance depends not only on the OLL of each 4-wire loop, but also on the one-way loss of each 4-wire loop and the 2-wire circuit loss between adjacent 4-wire loops. The one-way loss of 4-wire loops and the 2-wire circuit loss govern the interaction among 4-wire loops [4].

Because of accumulated impairments and interactions, the OLL of each 4-wire loop in a connection with multiple 4-wire loops has to be much higher than that in a single 4-wire loop connection in order to achieve the same transmission performance. In a connection with multiple 4-wire loops, the effect of listener echo on voice-band data transmission is extremely significant. References [4] and [5] illustrate the relationship between voltage and power accumulation of listener echoes in a connection with multiple 4-wire loops. In general, uncorrelated echoes should be assumed for multiple 4-wire loop connections and the power addition criterion should be used to achieve satisfactory performance. This means that the OLL required for each 4-wire loop should be increased by 10 log m dB, where m is the total number of 4-wire loops. However, for connections with very low loss, the required increment for the OLL of each 4-wire loop may be 16.6 log m dB and for connections with intermediate loss, the addition of 13.3 log m dB may be necessary.

4 Limits of listener echo

4.1 Voice transmission

The degree to which listener echo affects the quality of a voice connection depends on two factors:

1) the Weighted Listener Echo Path Loss (WEPL); and

2) the round trip delay.

Transmission quality degrades when the WEPL is reduced and when the round trip delay is increased. See 2.8 for the definition of WEPL. The transmission planner must select appropriate values of WEPL and round trip delay to achieve a desired level of transmission quality for connections in a target population. The target population is that set of connections which it is, possible to construct and which involves the listener echo path or paths of interest. For example, take the simple case of connections involving subscriber lines connected through a digital local office. If any of the *N* subscriber lines can connect to any of the other *N* lines, then the target population of connections consists of the *N*(N-1)/2 possibilities.

Once the transmission planner has identified the target population of connections and the desired level of transmission quality, then the information contained in Recommendation P.11 and Supplement No. 3 can be used to calculate the minimum value of WEPL and maximum value of round trip delay required to provide that degree of transmission quality. To illustrate the procedure, an example is given in Figure 3 and Table 1. The information in the figure and table was derived for use in the North American network. Using the North American Transmission Rating Model found in Supplement No. 3, values of WEPL and round trip delay were calculated such that listener echo would add only a small additional impairment to the overall transmission quality. The objective that was used was a reduction of no more than 2% Good or Better average grade of service. The target population was the connections of subscriber loops through digital local offices.

The curves in Figure 3 and date in Table 1 are to be interpreted as follows. For a given desired (or required) value of round trip delay, no more than 50% of the connections in the target population may have WEPL less than the value given by the curve marked “50”, no more than 5% of connections may have WEPL less than the value given by the curve marked “95”, and so forth. For example, if the round trip delay is specified to be 4 ms, then in the target population no more than 50% of connections may have WEPL ≤ 18 dB, no more than 5% may have WEPL ≤ 13 dB, and no more than 1% may have WEPL ≤ 9 dB. In addition to the WEPL, the minimum value of singing margin for any connection in the target population must conform to Recommendation G.122.

After identifying the required maximum round trip delay, minimum WEPL, and minimum singing margin for the target population of connections, the transmission planner must then make sure that the equipment in the network [e.g. subscriber lines and telephones, 2/4-wire hybrids and balancing method(s)] and the network transmission loss/level plan are adequate to assure that these requirements are met for the target population of connections. This is not always easy to do. For example in the North American network it was necessary to equip the digital local switches with adjustable echo balancing networks, which can be automatically adjusted to achieve the best echo balance with the mix of subscriber lines in the network.

4.2 Voice-band data transmission

The following consideration provides an example and can serve as an indication of what values of OLL might be required by existing types of modems with a bit rate of up to 2.4 kbit/s, in order to obtain high quality data transmission:

– a complete connection should not contain more than five (exceptionally seven) physical loops;

– loops with very high OLL (exceeding, e.g. 45 dB) need not be included in the number of loops in the connection;

– the OLL of each loop at any frequency in the band 500-2500 Hz should not be less than the values indicated in Table 2 (based on OLL = 18 + 10 log *m*, where *m* = total number of loops).

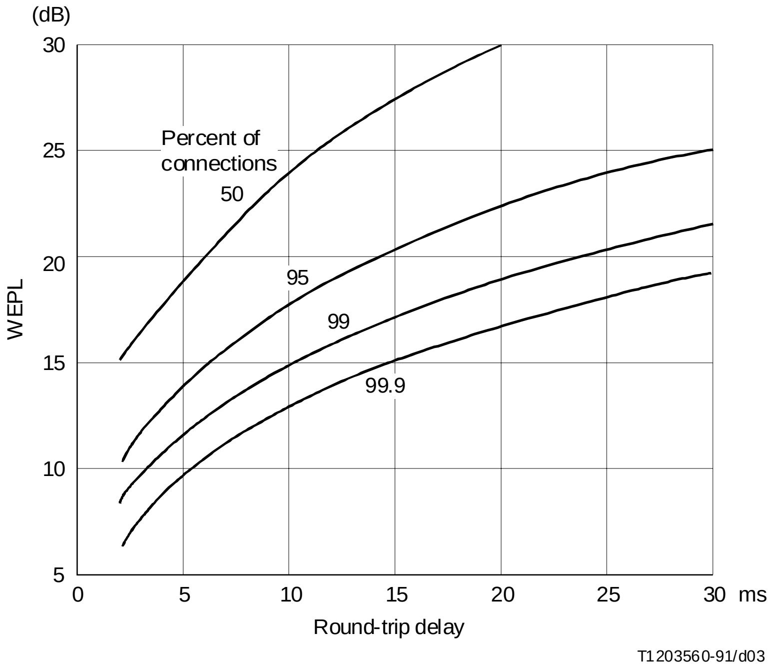

FIGURE 3/G.126

Weighted Listener Echo Path Loss (WEPL) objectives

TABLE 1/G.126

Planned values of WEPL

Round-trip delay (ms)	Minimum WEPL (dB)	
	For 99.9% of connections	For 50% connections
4	9	18
6	11	20
8	12	22
NOTE – For connections with multiple 4-wire loops an increment of 10 log *m* dB for WEPL of each 4-wire loop may be required, where *m* is the number of loops. The values is under study.		

TABLE 2/G.126

OLL and number of loops in a connection

In one national system		Maximum total number of loops in international connection
Number of national loops	OLL of each loop	
1	22,8 dB	3
2	25 dB	5
3	26,5 dB	7
NOTE – In general, the OLL in a single 4-wire loop connection may need to be at least 25 dB for high speed data with a bit rare of 4.8 kbit/s up to 9.8 kbit/s at any frequency in the band 500-2500 Hz.		

References

[1] CCITT Contribution COM XII-No. 208, study period 1985-1988.

[2] CAVANAUGH (J.R.), HATCH (R.W.) and NEIGH (J.L.): A model for the subjective effects of listener echo on telephone connections, *B.S.T.J.*, Vol. 59, No. 6, pp. 1009-1060, July-August 1980.

[3] CCITT Contribution COM XII-No. 173, study period 1985-1988.

[4] GRUBER (J.G.): Performance analysis and design guidelines for multiple 4-wire path telephone connections, *IEEE Trans. on Communications*, Vol. COM 34, pp. 647-653, July 1986.

[5] CCITT Contribution COM XII-No. 42, study period 1981-1984.