INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.114

(02/96)

TRANSMISSION SYSTEMS AND MEDIA

GENERAL CHARACTERISTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

ONE-WAY TRANSMISSION TIME

ITU-T Recommendation G.114

(Previously “CCITT Recommendation”)

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). 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, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation G.114 was revised by ITU-T Study Group 12 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 6th of February 1996.

NOTE

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

CONTENTS

SUMMARY

This Recommendation provides specifications for transmission time, including delay due to equipment processing time as well as propagation delay, in connections with echo adequately controlled. Recognising that the delay became a limited resource in modern networks, the Recommendation is intended to assist network operators as well as equipment manufacturers in controlling the detrimental effects of delay (without echo) on service quality. All services with overall performance which depend on user or terminal interactivity are considered.

This Recommendation is divided into three clauses. Clause 1 gives a general overview. Clause 2 provides recommendations for the end-to-end one-way transmission time limits. Clause 3 contains transmission time allocation guidelines for the national and international segments of the connection. Clause 3 guidelines apply only to the processing time portion of the delay. Additional information on how to estimate delay in international circuits and on the impact of long delays on the service quality is provided in the two annexes.

Recommendation G.114

ONE-WAY TRANSMISSION TIME

(Geneva, 1964; amended Mar del Plata, 1968; Geneva, 1980;
Malaga-Torremolinos, 1984; Melbourne, 1988; Helsinki, 1993; revised in 1996)

1 Introduction

Transmission time for connections with digital segments includes delay due to equipment processing as well as propagation delay, such that both types of delay can be significant contributors to overall transmission time. Guidance is especially needed for designers of telecommunications equipment that uses signal processing, causing increase in delay.

Historically a value of 400 ms was considered a meaningful limit for network planning purposes, where voice telephony was the focus. This value was not originally intended as guidance for equipment designers who, on an increasingly frequent basis, can substantially affect the transmission time by the amount of signal processing in their designs.

Transmission time is a very important parameter for any application whose overall performance is dependent on user or terminal interactivity. Applications such as voice, voice-band data, digital data, and videotelephony may involve user tasks or terminal equipment characteristics that vary substantially in their sensitivity to transmission delay. Because network and service providers cannot alter the transmission time characteristics nor transmission media between two Administrations, in response to all possible user tasks and applications, some highly interactive tasks may experience degradation even at delays on the order of 100 ms. Accordingly, it is critical that the delay (transmission time) be seen as a vital resource that is to be consumed with caution, and only when clear service benefits derive from it. This especially applies to delay associated with signal processing.

This Recommendation is intended to assist equipment designers and network planners in realizing acceptable services to users performing a wide variety of tasks with multiple applications. It is recognized that not all possible user applications and network configurations can be predicted, and that some user applications and network arrangements may combine processing delays and propagation times such that the total transmission time exceeds 400 ms.

A clear purpose of this Recommendation is thus to emphasize the need to consider the delay impact on evolving service applications, and indicate the desirability of avoiding delay increases, especially processing delays, whenever possible.

2 End-to-end transmission time limits

In consideration of the above points, the ITU-T *recommends* the following limits for one-way transmission time for connections with echo adequately controlled (see Note 1) according to Recommendation G.131 [1]:

- 0 to 150 ms: Acceptable for most user applications (see Note 2).
- 150 to 400 ms: Acceptable provided that Administrations are aware of the transmission time impact on the transmission quality of user applications (see Note 3).
- above 400 ms: Unacceptable for general network planning purposes; however, it is recognized that in some exceptional cases (see Note 4) this limit will be exceeded.

NOTES

1 The use of echo control equipment that introduces other impairments, such as speech clipping and noise contrast, may have to be controlled in order to achieve acceptable transmission quality.

2 Some highly interactive voice and data applications may experience degradation for values below 150 ms. Therefore, increases in processing delay on connections with transmission times even well below 150 ms should be discouraged unless there are clear service and application benefits.

3 For example, international connections with satellite hops that have transmission times below 400 ms are considered acceptable.

4 Examples of such exceptions are unavoidable double satellite hops, satellites used to restore terrestrial routes, fixed satellite and digital cellular interconnections, videotelephony over satellite circuits, and very long international connections with two digital cellular systems connected by long terrestrial facilities.

The recommended limits given here can be better interpreted if the information provided in Annex B is considered. For example, the voice quality test results indicate that, even in the complete absence of echo, 10% or more of the speakers may experience difficulty due to a delay of 400 ms. Increases in delay beyond this value will cause a further increase in unacceptable connections, especially for highly interactive conversations. To provision services with route diversity and restoration capabilities, Administrations may nonetheless choose to exceed 400 ms, on an exceptional basis. The data in Annex A provides guidance as to the service quality impact of such a decision.

3 Transmission time allocation

As transmission time becomes more of a limited resource in the modern digital networks, it is important to make an effort to minimize its increase caused by the introduction of new delay-prone technologies.

The delay allocation rules, recommended here, apply to the processing time only and do not include the propagation time portion of the total connection delay. The propagation time is determined by the distance and the speed of the signal in the transmission facility and can be controlled only in a very limited way by the network planners. The key factor is the geographical distance that differs widely within and between various countries. Also, in practice, the routing choices in international and national networks are often made for other than performance related reasons (e.g. economics, traffic considerations) with the facilities such as satellites or radio links, commonly used for routing diversity, representing large investment value that cannot be easily replaced.

In consideration of the above points, no more than 50 ms of one-way processing time is recommended for each of the national systems and for the international chain of circuits of an international connection (terrestrial or satellite) carrying speech signals. While the total processing time in any of these three parts of the international connection should be kept below 50 ms, the processing time is usually much less than this. For example, for the typical connection given in Recommendation G.801 [2] (see Figure 2/G.801), total processing time associated with switches, cross connects, multiplexers, etc., should be around 6 ms for a national system and 3 ms for the international chain. It should be noted that the recommended guidelines may be exceeded with today’s technology, if a worst case scenario is encountered (e.g. a very long international circuit with DCME and submarine optical fibre transmission systems, PLMS, etc.).

Annex A

Delay estimation for circuits

(This annex forms an integral part of this Recommendation)

In the establishment of the general interconnection plan within the limits in this Recommendation, the one-way transmission time of both the national extension circuits and the international circuits must be taken into account. The transmission time of circuits and connections is the aggregate of several components: e.g. group delay in cables and equipment processing times (e.g. digital switches), etc.

The planning values given in Table A.1 may be used to estimate the total transmission time of specified assemblies which may form circuits or connections.

A.1 Planning values of transmission time

Provisionally, the planning values of transmission time in Table A.1 may be used.

A.2 National extension circuits

The main arteries of the national network should consist of high-velocity propagation lines. In these conditions, the transmission time between the international centre and the subscriber farthest away from it in the national network can be estimated as follows:

a) in purely analogue networks, the transmission time will probably not exceed:

$$12 + (0.004 \times \text{distance in kilometres}) \text{ ms}$$

Here the factor 0.004 is based on the assumption that national trunk circuits will be routed over high-velocity plant (250 km/ms). The 12 ms constant term makes allowance for terminal equipment and for the probable presence in the national network of a certain quantity of loaded cables (e.g. three pairs of channel translating equipments plus about 160 km of H 88/36 loaded cables). For an average size country (see Figure 2/G.103 [3]) the one-way propagation time will be less than 18 ms;

b) in mixed analogue/digital networks, the transmission time can generally be estimated by the equation given for purely analogue networks. However, under certain unfavourable conditions increased delay may occur compared with the purely analogue case. This occurs in particular when digital exchanges are connected with analogue transmission systems through PCM/FDM equipments in tandem, or transmultiplexers. With the growing degree of digitization the transmission time will gradually approach the condition of purely digital networks;

c) in purely digital networks between local exchanges (e.g. an IDN), the transmission time as defined above will probably not exceed:

$$3 + (0.004 \times \text{distance in kilometres}) \text{ ms}$$

The 3 ms constant term makes allowance for one PCM coder or decoder and five digitally switched exchanges.

NOTE – The value 0.004 is a mean value for coaxial cable systems and radio-relay systems; for optical fibre systems 0.005 is to be used.

d) in purely digital networks between subscribers (e.g. an ISDN), the delay of c) above has to be increased by up to 3.6 ms if burst-mode (time compression multiplexing) transmission is used on 2-W local subscriber lines.

These values do not cover the additional delays introduced by PABXs and Private Branch Networks (PBNs).

A.3 International circuits

International circuits[1] will use high-velocity transmission systems, e.g. terrestrial cable or radio-relay systems, submarine systems or satellite systems. The planning values of A.1 may be used.

The magnitude of the mean one-way transmission time for circuits on high altitude communication satellite systems makes it desirable to impose some routing restrictions on their use. Details of these restrictions are given in Recommendation E.171 [4].

TABLE A.1/G.114

Transmission or processing system	Contribution to one-way transmission time	Remarks
Terrestrial coaxial cable or radio-relay system: FDM and digital transmission	4 µs/km	Allows for delay in repeaters and regenerators
Optical fibre cable system, digital transmission	5 µs/km (Note 6)	
Submarine coaxial cable system	6 µs/km	

---

[1] For short nearby links, telecommunications cables operated at voice frequencies may also be used in the conditions set out in the introduction to subclause 5.4 of Fascicle III.2 of the *Blue Book*.

TABLE A.1/G.114 *(continued)*

Transmission or processing system	Contribution to one-way transmission time	Remarks
Submarine optical fibre system: – transmit terminal; – receive terminal.	 13 ms 10 ms	Worst case
Satellite system: – 1400 km altitude; – 14 000 km altitude; – 36 000 km altitude.	 12 ms 110 ms 260 ms	Propagation through space only (between earth stations)
FDM channel modulator or demodulator	0.75 ms (Note 1)	Half the sum of transmission times in both directions of transmission
FDM compandored channel modulator and demodulator	0.5 ms (Note 2)	
PCM coder and decoder (Rec. G.712)	0.75 ms (Note 1)	
ADPCM (Recs. G.721, G.726, G.727) codec	0.25 ms	
PCM/ADPCM/PCM transcoding	0.5 ms	
LD-CELP G.728 coder and decoder	2.0 ms	
CS-ACELP 8 kbit/s; G.729 coder and decoder	15 ms (Note 7)	
PLMS (Public Land Mobile System) – objective 40 ms	80-110 ms	
H.260-Series video coders and decoders	Further study (Note 8)	
DCME (Rec. G.763) per pair: – with speech and non-remodulated VBD; – with remodulated VBD.	 30 ms 350 ms	
PCME (Rec. G.764) per pair: – with speech and non-remodulated VBD; – with remodulated VBD.	 35 ms 70 ms	
Transmultiplexer	1.5 ms (Note 3)	
Digital transit exchange, digital-digital	0.45 ms (Note 4)	
Digital local exchange, analogue-analogue	1.5 ms (Note 4)	
Digital local exchange, analogue subscriber line-digital junction	0.975 ms (Note 4)	
Digital local exchange, digital subscriber line-digital junction	0.825 ms (Note 4)	
Echo cancellers	0.5 ms (Note 5)	
ATM (CBR using AAL1)	6.0 ms (Note 9)	

TABLE A.1/G.114 *(concluded)*

NOTES

1 These values allow for group-delay distortion around frequencies of peak speech energy and for delay of intermediate higher order multiplex and through-connecting equipment.

2 This value refers to FDM equipment designed to be used with a compandor and special filters.

3 For satellite digital communications where the transmultiplexer is located at the earth station, this value may be increased to 3.3 ms.

4 These are mean values: depending on traffic loading, higher values can be encountered, e.g. 0.75 ms (1.950 ms, 1.350 ms, or 1.250 ms) with 0.95 probability of not exceeding. (For details see Recommendation Q.551.)

5 This is averaged for both directions of transmission.

6 This value is provisional and is under study.

7 Algorithmic delay only. It should be noted that G.729 coding system introduces a total delay made up of algorithmic delay (fixed) plus processing delay (variable with technology). Processing delay does not exceed the algorithmic delay value in real-time applications.

8 Further study required. Delay for these devices is usually non-constant, and the range varies by implementation. Current implementations are on the order of several hundred milliseconds and considerable delay is added to audio channels to achieve lip-synchronization. Manufacturers are encouraged to reduce their contribution to transmission time, in accordance with this Recommendation.

9 This is the cell formation delay of 64 kbit/s stream when it completely fills the cell (one voice channel per VC). In practical applications, additional delay will result, e.g. from cell loss detection and buffering. Other delays may be applicable to other AALs and cell mapping arrangements, and are for further study.

Annex B

Long delay considerations for telephone, videotelephone and videoconference circuits

(This annex forms an integral part of this Recommendation)

B.1 Introduction

International connections (see Figure 1/G.103) comprising submarine cables may involve a maximum one-way transmission delay of about 170 ms.

A one hop satellite connection even with an ISL (Inter-Satellite Link) of moderate length introduces one-way transmission delay within the recommended limit of 400 ms. However, a careful analysis of the additional probable delay contributions by digital signal processing (e.g. TDMA, DSI, DCME, 16 kbit/s, 32 kbit/s and lower bit rate encoding, bit-regeneration, packet-switching, etc.), among other sources, shows that in some cases the recommended limit of 400 ms mean one-way transmission time might be exceeded.

In light of recent technical improvements in echo-control techniques and considering that fixed processing delays may reach hundreds of milliseconds in some currently designed systems (e.g. low bit rate digital mobile systems), it is important to understand also the effects of delay, in the absence of echo, on communications. This annex addresses this issue.

The 4-wire circuits provide a close approximation to echo-free connections, assuming adequate acoustic coupling loss across the handset. In the long run, with expansion of the ISDN implementation, use of 4-wire circuits is expected to grow. However, 2-wire circuits and their accompanying hybrid connection, as well as other components causing echo, are still likely to be present in varying degrees during the foreseeable future. Thus, the use of modern echo cancellers in satellite circuits is currently regarded as the most effective method for overcoming the echo problem, provided that the characteristics of the echo path to be modelled by the echo canceller are linear and time invariant, or varying only slowly compared with the convergence speed of the echo canceller.

A brief discussion of delay effect, in the absence of echo, on communication quality is provided below.

B.2 Effect of long transmission delays on the subscriber

B.2.1 Effects of echo cancellers

In 1987, a series of tests was performed to determine the effectiveness of echo cancellers in terrestrial and satellite circuits, using echo cancellers conforming to Recommendation G.165 [13] and a callback interview procedure as per Annex A/P.82 [14]. Details of the procedure were presented in [15] and a summary of the results is shown in Figure B.1, giving a plot of the per cent difficulty as a function of one-way transmission time. A one-way delay value of 45 ms over terrestrial circuits was taken as a reference, and the effect of increasing the delay value to 300 ms and 500 ms over terrestrial and satellite links was evaluated.

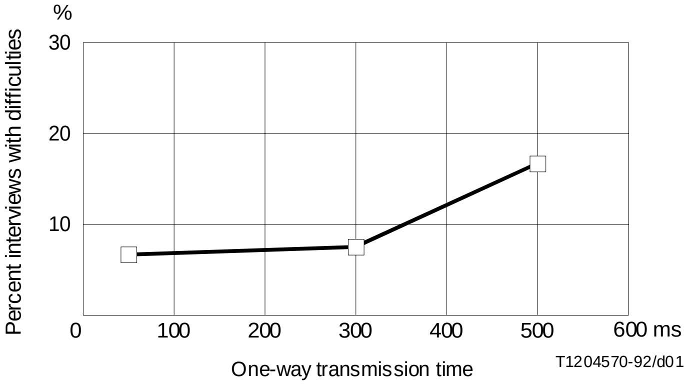

FIGURE B.1/G.114

Effect of long one-way transmission times on the difficulty of conversation with echo cancellers in the circuit

These results show that no significant difference between 45 ms and 300 ms delays resulted for the “per cent difficulty” score. At a 500 ms delay, the per cent difficulty score approximately doubled (from 7.3% to 15.8%), but this value is still considerably smaller than earlier results of over 60% obtained with echo suppressors.

The above results support the view that connections with delays somewhat greater than 400 ms may be accepted provided that echo cancellers conforming to the specifications of Recommendation G.165 or other echo control devices with equivalent performance are used.

B.2.2 Effects of delay on dynamics of conversation

The most recent evidence presented by some Administrations suggests that the performance degradation due to conversation dynamics impairments is noticeable even below 400 ms one-way delay limit. This effect can be observed when structured interactive tasks and selected sensitive measures are employed in subjective experimentation.

In 1989 a series of subjective experiments was conducted [16] to determine the impact of the delay on the conversational characteristics deemed to be important in a business-type environment. A structured conversational task coupled with objective and subjective measures of the temporal dynamics of the conversation were developed and used in the experiment. Subjective measures included ratings on the ease of interruption, the necessity of repeating utterances, the attentiveness, responsiveness and helpfulness of the partner. Standard overall quality MOS rating was also used. The results are shown in Figure B.2.

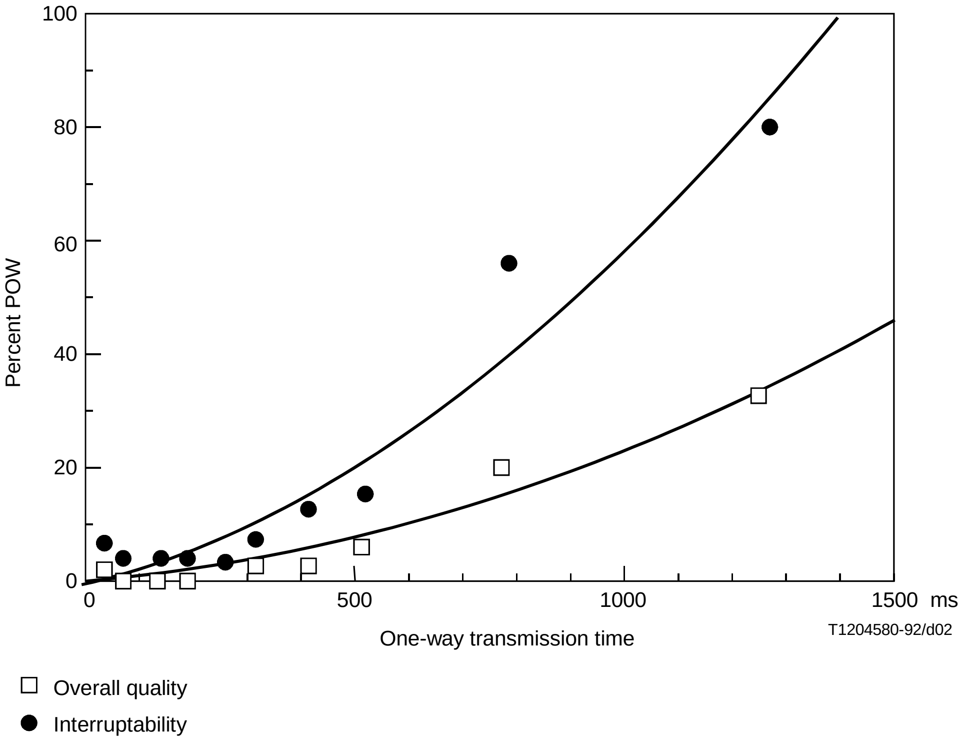

FIGURE B.2/G.114

Comparison of POW for overall quality and interruptability

A subjective test intended to evaluate the effects of pure delay on speech quality was completed in 1990 [17]. The test was designed to obtain subjective reactions, in the context of interruptability and quality, to echo-free telephone circuits in which various amounts of delay were introduced. The results indicated that long delays did not greatly reduce mean opinion scores over the range of delay tested, viz. 0 to 1000 ms of one-way delay. In addition, the measure of interruptability did not show the divergence from overall quality to be as significant as indicated in Figure B.2. However, observations during the test and subject interviews after the test showed the subjects experienced some real difficulties in communicating at the longer delays, although subjects did not always associate the difficulty with the delay.

A second subjective test [18] intended to evaluate the effects of pure delay on telephone connections used by volunteer Telco customers was completed in 1991. The calls from these customers were routed through a laboratory where varying amounts of delay, viz. 0 to 750 ms of one-way delay was added. The test results showed that calls with (one-way delay): 0 ms of inserted delay were rated “good”; 250 ms of inserted delay were rated “fair”; and 500 ms of inserted delay were rated “poor”. These results are presented in Figure B.3.

Similar experiments are described in [19], [20] and [21]. The following is a highlight of the results presented in [20].

The effect of delay was measured using a combination of objective physical parameters related to efficiency of a conversation. It was studied using the following six different conversational modes (tasks):

- Task 1: Read out random numbers as quickly as possible in turn.

- Task 2: Verify random numbers as quickly as possible in turn.

- Task 3: Complete words with lost letters as quickly as possible by exchanging information.
- Task 4: Verify city names as quickly as possible in turn.
- Task 5: Determine the shape of a figure by receiving oral information.
- Task 6: Free conversation.

Subjective opinion tests were performed and delay detectability thresholds. Mean Opinion Scores (MOS) and conversation efficiency were obtained. Figure B.4 shows detectability thresholds for various conversational tasks. The results show that the subjective quality as a function of delay varies depending on a conversational mode and subject group (trained, untrained).

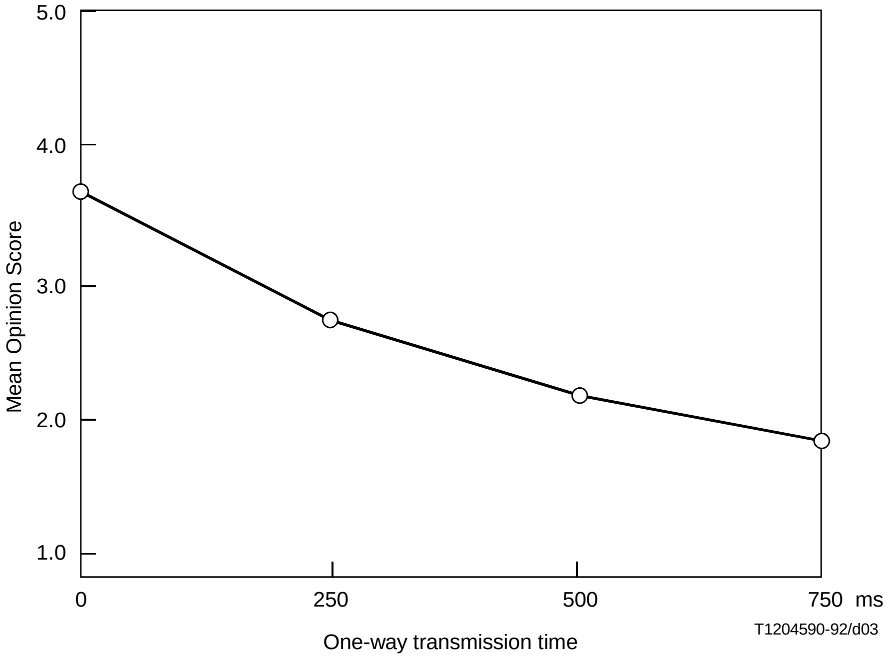

FIGURE B.3/G.114

Mean Opinion Scores (MOS) for the four delay conditions

In Figure B.4, the detectability threshold for round trip delay was defined as the delay detected by 50% of a task's subjects and provides some guidance to network planners in providing acceptable service to the user.

B.2.3 Interaction between delay and user applications

Tests were performed to assess the interaction between delay and user applications. In these tests a comparison of telephone conversations with videophone were made and it was shown that there is little difference between both types of connection. Figure B.5 shows the degradations of MOS, using a condition without delay as ANCHOR [22].

A methodology for objective assessment of the effects of delay on speech communication in real networks was derived using the results of the above subjective experiments.

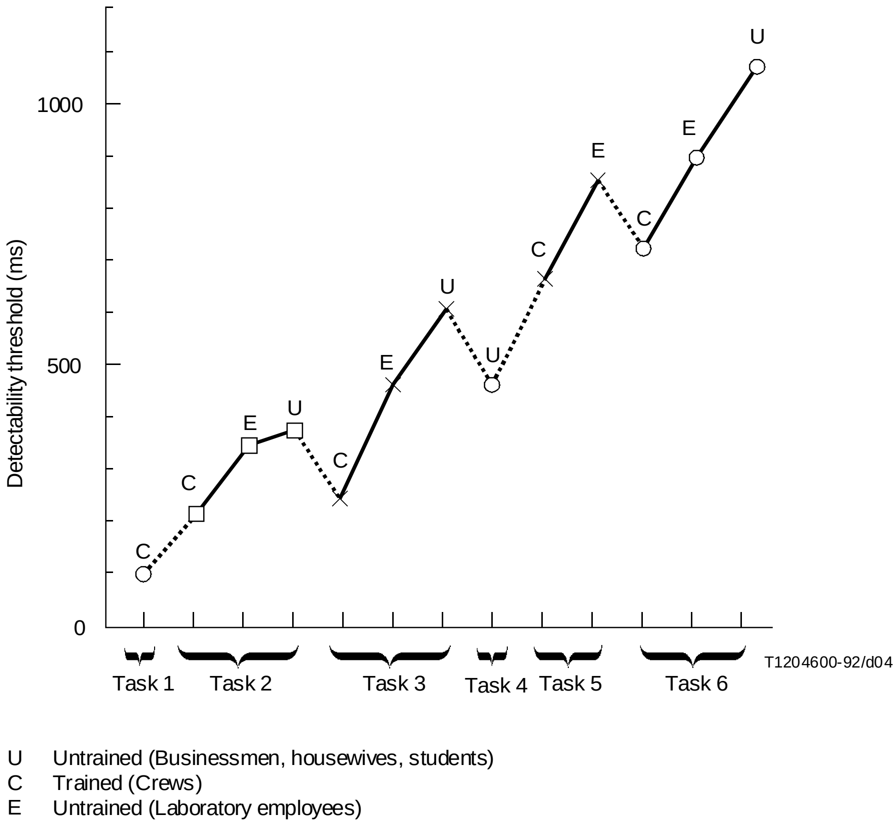

FIGURE B.4/G.114

Detectability thresholds for various conversational models

The information on temporal characteristics and their correlation to subjective opinions was extracted from the subjective data. This data was then used to formulate equations predicting detectability threshold and MOS as a function of delay. The effects of the delay on performance in commercial networks can be estimated by measuring the basic temporal parameters from the real life traffic and then using this data to calculate the objective measures applying the experimentally derived equations.

Table B.1 presents an example of the results obtained using this methodology for a commercial circuit.

In 1992 a study was performed to assess the subjective impact of end-to-end transmission delay in audiovisual communications [23]. The experimental conditions included three point-to-point videophone connections with 200, 450 and 700 ms of one-way transmission delays. Subjects engaged in a series of five-minute long conversations and were interrogated at the end of each condition, as well as after the whole session. The results are summarized in Table B.2. Similar results were obtained from a videotelephony test [24].

B.3 Summary and conclusions

The transmission impairments associated with long delay circuits are best analysed by separating the echo-induced degradation and the subjective difficulty due to pure delay. Appropriate use of echo cancellers has been shown to indeed provide international or national satellite connections yielding quality and performance practically equivalent to the terrestrial connections for telephony. These results only refer to electric echo and additional studies are necessary to determine the effect of acoustic echo.

Thus, under these conditions, the dominant impairments are associated with the pure delay component.

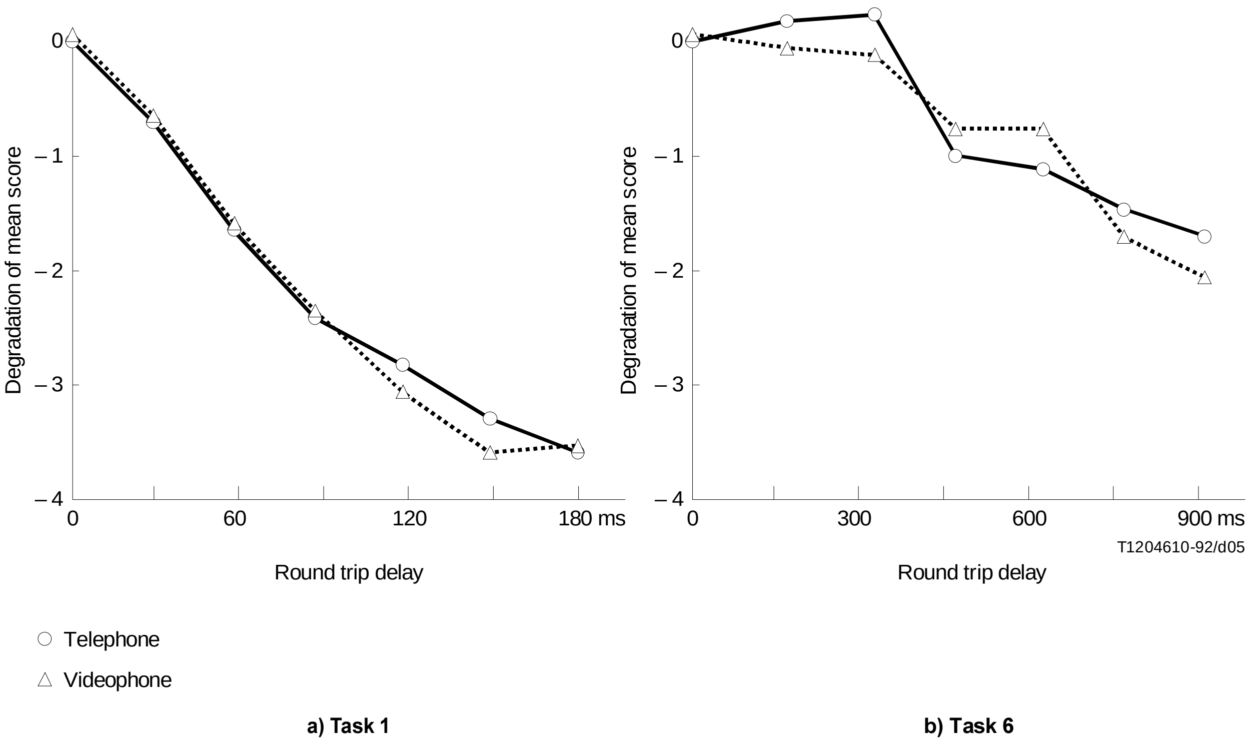

FIGURE B.5/G.114

Effects of delay on communications quality for telephone and videophone

TABLE B.1/G.114

Effect of delay on speech quality in a real network

Conversation mode	Quality	Cumulative distribution (%)	Detectability threshold (Round trip delay ms)
Type of commercial call	Task 1	0.1	90
	Task 2	1	210
	Task 3	9	290
	Task 4	21	480
	Task 5	86	680
	Task 6	80	740
NOTE – More information on this table is given in [20].			

TABLE B.2/G.114

Variation of subjective performance for three end-to-end videophone connections

	One-way transmission delays		
	200 ms	450 ms	700 ms
MOS connection quality	3.74 ± 0.52	3.69 ± 0.51	3.48 ± 0.48
MOS ease of interruption	4.00 ± 0.55	3.79 ± 0.53	3.56 ± 0.49
Communication difficulty	28 ± 4%	35 ± 5%	46 ± 6%
Connection acceptability	80 ± 11%	78 ± 11%	73 ± 10%
NOTE – MOS values were derived on the basis of a five point (1 to 5) scale. All errors are defined at a 95% level of confidence.			

Recently presented information suggests that:

- The effects of pure delay (no echo) on conversation dynamics can be detected well below 400 ms one-way delay if subjective experiments employ highly interactive tasks and subjective measures related to specific conversational difficulties, such as ability to interrupt, are used.
- The effects of pure delay (no echo) on speech quality appear to moderately increase as the delay is increased.

However, as a standard set of tests has not been agreed to, obtained experimental results depend upon the type of activity selected to evaluate the impact of delay and experimental results vary significantly from laboratory to laboratory. Thus, designers must determine the type of services, and hence the communication interactivity needs, that will be carried if the performance of the system is to be appropriately evaluated.

References

[1] CCITT Recommendation G.131 (1988), *Stability end echo*.

[2] CCITT Recommendation G.801 (1988), *Digital transmission models*.

[3] CCITT Recommendation G.103 (1988), *Hypothetical reference connections*.

[4] CCITT Recommendation E.171 (1988), *International telephone routing plan*.

[5] CCITT Recommendation G.726 (1990), *40, 32, 24, 16 kbit/s Adaptive Differential Pulse Code Modulation (ADPCM).*

[6] CCITT Recommendation G.727 (1990), *5-, 4-, 3- and 2-bits/sample embedded Adaptive Differential Pulse Code Modulation (ADPCM).*

[7] CCITT Recommendation G.728 (1992), *Coding of speech at 16 kbit/s using low-delay code excited linear prediction*.

[8] ITU-T Recommendation G.173 (1993), *Transmission planning aspects of the speech service in digital public land mobile networks*.

[9] ITU-T Recommendation H.261 (1993), *Video codec for audiovisual services at p × 64 kbit/s*.

[10] ITU-T Recommendation G.763 (1994), *Digital circuit multiplication equipment using ADPCM (Recommendation G.726) and digital speech interpolation*.

[11] CCITT Recommendation G.764 (1990), *Voice packetization – Packetized voice protocols*.

[12] ITU-T Recommendation Q.551 (1994), *Transmission characteristics of digital exchanges*.

[13] ITU-T Recommendation G.165 (1993), *Echo cancellers*.

[14] CCITT Recommendation P.82 (1988), *Method for evaluation of service from the standpoint of speech transmission quality*.

[15] CCITT Contribution COM XII-177 (1987), COMSAT, USA.

[16] CCITT Delayed Contribution D.21 (1989), Bell-Northern Research, Canada.

[17] CCITT Contribution COM XII-62 (1990), Bellcore, USA.

[18] CCITT Delayed Contribution D.131 (1992), Bellcore, USA.

[19] CCITT Contribution COM XII-94 (1991), CSELT, Italy.

[20] CCITT Contribution COM XII-85 (1991), NTT, Japan.

[21] CCITT Delayed Contribution D.80 (1991), Royal PTT, The Netherlands.

[22] CCITT Contribution COM XII-84 (1991), NTT, Japan.

[23] CCITT Delayed Contribution D.126 (1992), COMSAT, USA.

[24] CCITT Delayed Contribution D.128 (1992), CSELT, Italy.