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OF ITU

Q.706

(03/93)

SPECIFICATIONS OF SIGNALLING SYSTEM No. 7

SIGNALLING SYSTEM No. 7 – MESSAGE TRANSFER PART SIGNALLING PERFORMANCE

ITU-T Recommendation Q.706

(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 Q.706 was revised by the ITU-T Study Group XI (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

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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 Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.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.

CONTENTS

INTRODUCTION

The Message Transfer Part (MTP) of Signalling System No. 7 (SS No. 7) is designed as a joint transport system for the messages of different users. The requirements of the different users have to be met by the Message Transfer Part (MTP). These requirements are not necessarily the same and may differ in importance and stringency.

In order to satisfy the individual requirements of each user, the MTP is designed in such a way that it meets the most stringent User Part requirements envisaged at the time of specification. To this end, the requirements of the telephone service, the data transmission service and the signalling network management, in particular, were investigated. It is assumed that a signalling performance which satisfies the requirements mentioned above will also meet those of future users.

In the light of the above, signalling system performance is understood to be the capability of the MTP to transfer messages of variable length for different users in a defined manner. In order to achieve a proper signalling performance, three groups of parameters have to be taken into account:

- The first group covers the objectives derived from the requirements of the different users. The aims are limitation of message delay, protection against all kinds of failures and guarantee of availability.
- The second group covers the features of the signalling traffic, such as the loading potential and the structure of the signalling traffic.
- The third group covers the given environmental influences, such as the characteristics (e.g. error rate and proneness to burst) of the transmission media.

The three groups of parameters are considered in the specification of the procedures to enable the MTP to transfer the messages in such a way that the signalling requirements of all users are met and that a uniform and satisfactory overall signalling system performance is achieved.

SIGNALLING SYSTEM No. 7 – MESSAGE TRANSFER PART SIGNALLING PERFORMANCE

(Geneva, 1980; modified at Helsinki, 1993)

1 Basic parameters related to MTP signalling performance

Signalling performance is defined by a great number of different parameters. In order to ensure a proper signalling performance for all users to be served by the common MTP, the following design objectives are established for the MTP.

1.1 Unavailability of a signalling route set

The unavailability of a signalling route set is determined by the unavailability of the individual components of the signalling network (signalling links and the signalling points) and by the structure of a signalling network.

The unavailability of a signalling route set should not exceed a total of 10 minutes per year.

The unavailability of a signalling route set within a signalling network may be improved by replication of signalling links, signalling paths and signalling routes.

1.2 Unavoidable MTP malfunction

The MTP is designed to transport messages in a correct sequence. In addition, the messages are protected against transmission errors. However, a protection against transmission errors cannot be absolute. Furthermore, missequencing and loss of messages in the MTP cannot be excluded in extreme cases.

For all User Parts, the following conditions are guaranteed by the MTP:

a) *Undetected errors*

On a signalling link employing a signalling data link which has the error rate characteristic as described in Recommendation Q.702 not more than one in 10^{10} of all message signal units will contain an error that is undetected by the MTP.

b) *Loss of messages*

Not more than one in 10^7 messages will be lost due to failure in the MTP.

c) *Messages out-of-sequence*

Not more than one in 10^{10} messages will be delivered out-of-sequence to the User Parts due to failure in the MTP. This value also includes duplication of messages.

1.3 Message transfer times

This parameter includes:

- handling times at the signalling points (see 4.3);
- queueing delays including retransmission delays (see 4.2);
- signalling data link propagation times.

1.4 Signalling traffic throughput capability

Needs further study (see 2.2).

2 Signalling traffic characteristics

2.1 Labelling potential

The design of Signalling System No. 7 provides the potential for labels to identify 16 384 signalling points. For each of the 16 different User Parts a number of user transactions may be identified, e.g. in the case of the telephone service up to 4096 speech circuits.

2.2 Loading potential

Considering that the load per signalling channel will vary according to the traffic characteristics of the service, to the user transactions served and to the number of signals in use, it is not practicable to specify a general maximum limit of user transactions that a signalling channel can handle. The maximum number of user transactions to be served must be determined for each situation, taking into account the traffic characteristics applied so that the total signalling load is held to a level which is acceptable from different points of view.

With regard to signalling route set congestion (see 11.2.3/Q.704), the last method referred to in 11.2.3.1 ii) b), the congested link method of deciding when to send a Transfer Controlled message, has advantages in the case of asymmetrical load distribution within a link set.

When determining the normal load of the signalling channel, account must be taken of the need to ensure a sufficient margin for peak traffic loads.

The loading of a signalling channel is restricted by several factors which are itemized below.

2.2.1 Queueing delay

The queueing delay in absence of disturbances is considerably influenced by the distribution of the message length and the signalling traffic load (see 4.2).

2.2.2 Security requirements

The most important security arrangement is redundancy in conjunction with changeover. As load sharing is applied in normal operation, the load on the individual signalling channels has to be restricted so that, in the case of changeover, the queueing delays do not exceed a reasonable limit. This requirement has to be met not only in the case of changeover to one predetermined link but also in the case of load distribution to the remaining links.

2.2.3 Capacity of sequence numbering

The use of 7 bits for sequence numbering finally limits the number of signal units sent but not yet acknowledged to the value of 127.

In practice this will not impose a limitation on the loading potential.

2.2.4 Signalling channels using lower bit rates

A loading value for a signalling channel using bit rates of less than 64 kbit/s will result in greater queueing delays than the same loading value for a 64 kbit/s signalling channel.

2.3 Structure of signalling traffic

The MTP serves different User Parts as a joint transport system for messages. As a result, the structure of the signalling traffic largely depends on the types of User Parts served. It can be assumed that at least in the near future the telephone service will represent the main part of the signalling traffic also in integrated networks.

It cannot be foreseen yet how the signalling traffic is influenced by the integration of existing and future services. The traffic models given in 4.2.4 have been introduced in order to consider as far as possible the characteristics and features of different services within an integrated network. If new or more stringent requirements are imposed on signalling (e.g. shorter delays) as a consequence of future services, they should be met by appropriate dimensioning of the load or by improving the structure of the signalling network.

3 Parameters related to transmission characteristics

No special transmission requirements are envisaged for the signalling links of Signalling System No. 7. Therefore, System No. 7 provides appropriate means in order to cope with the given transmission characteristics of ordinary links. The following items indicate the actual characteristics to be expected – as determined by the responsible Study Groups – and their consequences on the specifications of the MTP.

3.1 Application of Signalling System No. 7 to 64 kbit/s links

The MTP is designed to operate satisfactorily with the following transmission characteristics:

a) a long term bit error rate of the signalling data link of less than 10^{-6} [1];

b) a medium term bit error rate of less than 10^{-4};

c) random errors and error bursts including long bursts which might occur in the digital link due to, for instance, loss of frame alignment or octet slips in the digital link. The maximum tolerable interruption period is specified for the signal unit error rate monitor (see 10.2/Q.703).

3.2 Application of Signalling System No. 7 to links using lower bit rates

Needs further study.

3.3 Signalling link delays over terrestrial and satellite links

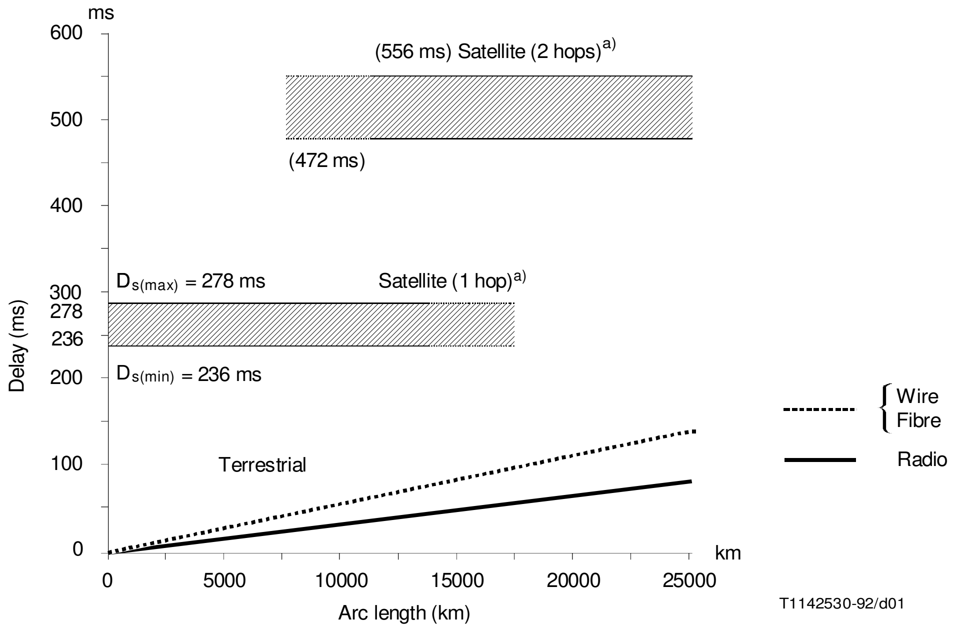
Data Channel Propagation Time (T_p) is defined in 4.3.2.4. It depends on transmission speed, the distance between nodes, repeater spacing and the delays in the repeaters. Transmission speed and repeater delays depend on the type of medium used to transmit the messages. Four types of medium are considered: wire, fibre optic cable, terrestrial radio and satellite systems. (Wire systems comprise standard underground copper cables and undersea cables.)

Table 1 provides representative delay values and Figure 1 shows those results graphically for the various transmission media.

TABLE 1/Q.706

Calculated terrestrial transmission delays for various call distances

Arc length (km)	Delay terrestrial (ms)		
	Wire	Fibre	Radio
500	2.4	2.50	1.7
1 000	4.8	5.0	3.3
2 000	9.6	10.0	16.6
5 000	24.0	25.0	16.5
10 000	48.0	50.0	33.0
15 000	72.0	75.0	49.5
17 737	85.1	88.7	58.5
20 000	96.0	100.0	66.0
25 000	120.0	125.0	82.5



[a] Delay varies with distances of each earth station from point on the Earth over which the satellite is located. (See Annex A.)

FIGURE 1/Q.706

Transmission delays using satellite and terrestrial message handling facilities

The double hop values do not take into consideration any terrestrial extensions and repeaters that may be required.

Formulae for computing the transmission delays are given in Annex A along with the assumptions made.

Due to the longer delay of satellite links and the longer terrestrial links, the message transfer times increase (see clause 5). Therefore care must be taken in the design of signalling networks if they are to meet the overall delay performance criterion (see Recommendation Q.709).

4 Parameters of influence on signalling performance

4.1 Signalling network

Signalling System No. 7 is designed for both associated and non-associated applications. The reference section in such applications is the signalling route set, irrespective of whether it is served in the associated or quasi-associated mode of operation.

For every signalling route set in a signalling network, the unavailability limit indicated in 1.1 has to be observed irrespective of the number of signalling links in tandem of which it is composed.

In planning SS No. 7 signalling networks to meet E.721, E.723 and I.352 delay requirements, consideration should be given to

- processing delays in SPs;
- number of SPs;
- number of STPs;

– number of signalling links;
– propagation delays of each signalling link;
– signalling link loading;
– message length mix.

4.1.1 International signalling network

Needs further study.

4.1.2 National signalling network

Needs further study.

4.2 Queueing delays

The MTP handles messages from different User Parts on a time-shared basis. With time-sharing, signalling delay occurs when it is necessary to process more than one message in a given interval of time. When this occurs, a queue is built up from which messages are transmitted in order of their times of arrival.

There are two different types of queueing delays: queueing delay in the absence of disturbances and total queueing delay.

4.2.1 Assumptions for derivation of the formulas

The queueing delay formulas are basically derived from the $M/G/1$ queue with priority assignment. The assumptions for the derivation of the formulas in the absence of disturbances are as follows:

a) the interarrival time distribution is exponential (M);

b) the service time distribution is general (G);

c) the number of server is one (1);

d) the service priority refers to the transmission priority within level 2 (see 11.2/Q.703); however, the link status signal unit and the independent flag are not considered;

e) the signalling link loop propagation time is constant including the process time in signalling terminals; and

f) the forced retransmission case of the preventive cyclic retransmission method is not considered.

In addition, for the formulas in the presence of disturbances, the assumptions are as follows:

g) the transmission error of the message signal unit is random;

h) the errors are statistically independent of each other;

i) the additional delay caused by the retransmission of the erroneous signal unit is considered as a part of the waiting time of the concerned signal unit; and

j) in case of the preventive cyclic retransmission method, after the error occurs, the retransmitted signal units of second priority are accepted at the receiving end until the sequence number of the last sent new signal unit is caught up by that of the last retransmitted signal unit.

Furthermore, the formula of the proportion of messages delayed more than a given time is derived from the assumption that the probability density function of the queueing delay distribution may be exponentially decreasing where the delay time is relatively large.

4.2.2 Factors and parameters

a) The notations and factors required for calculation of the queueing delays are as follows:

Q_a Mean queueing delay in the absence of disturbances

σ_2^a Variance of queueing delay in the absence of disturbances

Q_t Mean total queueing delay

σ_t^2 Variance of total queueing delay

$P(T)$ Proportion of messages delayed more than T

a Traffic loading by message signal units (MSU) (excluding retransmission)

T_m Mean emission time of message signal units

T_f Emission time of fill-in signal units

T_L Signalling loop propagation time including processing time in signalling terminal

P_u Error probability of message signal units

$$k_1 = \frac{\text{2nd moment of message signal units emission time}}{T_m^2}$$

$$k_2 = \frac{\text{3rd moment of message signal units emission time}}{T_m^3}$$

$$k_3 = \frac{\text{4th moment of message signal units emission time}}{T_m^4}$$

NOTE – As a consequence of zero insertion at level 2 (see 3.2/Q.703), the length of the emitted signal unit will be increased by approximately 1.6 percent on average. However, this increase has negligible effect on the calculation.

b) The parameters used in the formulas are as follows:

$$t_f = T_f/T_m$$
$$t_L = T_L/T_m$$

for the basic method,

$$E_1 = 1 + P_u t_L$$
$$E_2 = k_1 + P_u t_L (t_L + 2)$$
$$E_3 = k_2 + P_u t_L (t_L^2 + 3t_L + 3k_1)$$

for the preventive cyclic retransmission (PCR) method,

$a_3 = \exp(-at_L)$: traffic loading caused by fill-in signal units.

$a_z = 1 - a - a_3$

$H_1 = at_L$

$H_2 = at_L(k_1 + at_L)$

$H_3 = at_L(k_2 + 3at_L k_1 + a^2 t_L^2)$

$F_1 = at_L/2$

$F_2 = at_L(k_1/2 + at_L/3)$

$F_3 = at_L(k_2/2 + at_L k_1 + a^2 t_L^2/4)$

$$q_a = \frac{k_1 (a + a_z) + a_3 t_f}{2(1 - a)}$$

$$s_a = \frac{ak_1}{1 - a} q_a + \frac{k_2 (a + a_z) + a_3 t_f^2}{3(1 - a)}$$

$$t_a = \frac{3ak_1 s_a + 2ak_2 q_a}{2(1 - a)} + \frac{(a + a_z)k_3 + a_3 t_f^3}{4(1 - a)}$$

$$Z_1 = 2 + P_u(1 + H_1)$$

$$Z_2 = 4K_1 + P_u(5k_1 + 3H_1 + H_2)$$

$$Z_3 = 8k_2 + P_u(19k_2 + 27k_1 H_1 + 9H_2 + H_3)$$

$$Y_2 = s_a + 4k_1 + F_2 + 2\{q_a(2 + F_1) + 2F_1\}$$

$$Y_3 = t_a + 8k_2 + F_3 + 3\{s_a(2 + F_1) + q_a(4k_1 + F_2) + 2F + 2 + 4k_1 F_1\} + 12 q_a F_1$$

$$\alpha = \frac{1 - a\{2 + P_u(1 + at_L)\}}{2 + q_a + at_L/2}$$

$$q_d = \frac{aZ_2 + \alpha Y_2}{2(1 - aZ_1)}$$

$$s_d = \frac{aZ_2}{1 - aZ_1} q_d + \frac{aZ_3 + \alpha Y_3}{3(1 - aZ_1)}$$

$$q_b = \frac{q_a + 1 + F_1}{1 - a}$$

$$s_b = \frac{s_a + k_1 + F_2}{(1 - a)^3} + \frac{2\{q_a(1 + F_1) + F_1\}}{(1 - a)^2}$$

$$q_c = \frac{q_d + 1 + P_u(1 + H_1)}{1 - a}$$

$$s_c = \frac{s_d + k_1 + P_u(3k_1 + H_2)}{(1 - a)^3} + 2 \frac{q_d + P_u\{q_d(1 + H_1) + 2H_1\}}{(1 - a)^2}$$

$$P_v = P_u a \frac{q_a + 2 + at_L / 2}{1 - 2a} \left(1 + P_u \frac{a + a^2 t_L}{1 - 2a} \right)$$

4.2.3 Formulas

The formulas of the mean and the variance of the queueing delays are described in Table 2. The proportion of messages delayed more than a given time T_x is:

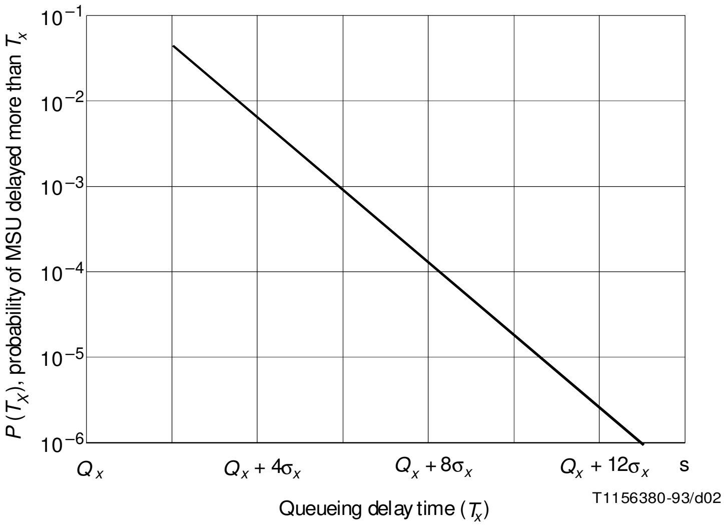
$$P(T_x) \cong \exp\left(- \frac{T_x - Q_x + \sigma_x}{\sigma_x} \right)$$

where Q_x and σ_x denote the mean and the standard deviation of queueing delay, respectively. This approximation is better suited in absence of disturbances. In the presence of disturbances the actual distribution may be deviated further. Relation between $P(T_x)$ and T_x is shown in Figure 2.

TABLE 2/Q.706

Queueing delay formula

Error correction method	Disturbance	Mean Q	Variance σ^2
Basic	Absence	$\frac{Q_a}{T_m} = \frac{t_f}{2} + \frac{ak_1}{2(1 - a)}$	$\frac{\sigma_a^2}{T_m^2} = \frac{t_f^2}{12} + \frac{a[4k_2 - (4k_2 - 3k_1^2)a]}{12(1 - a)^2}$
	Presence	$\frac{Q_t}{T_m} = \frac{t_f}{2} + \frac{aE_2}{2(1 - aE_1)} + E_1 - 1$	$\frac{\sigma_t^2}{T_m^2} = \frac{t_f^2}{12} + \frac{a[4E_3 - (4E_1 E_3 - 3E_2^2)a]}{12(1 - aE_1)^2}$ $+ Pu(1 - P_u)\, t_L^2$
Preventive cyclic retransmission	Absence	$\frac{Q_a}{T_m} = q_a$	$\frac{\sigma_t^2}{T_m^2} = s_a \ q_a^2$
	Presence	$\frac{Q_t}{T_m} = (1 - P_u - P_v)\, q_a$ $+ P_u q_b + P_v q_c$	$\frac{\sigma_t^2}{T_m^2} = (1 - P_u - P_v)\ s_a$ $+ P_u s_b + P_v s_c - \frac{\text{Qs}(2,t)}{T_m^2}$



Q_x Mean queueing delay (see Figure 3)
σ_x Standard deviation (see Figure 4)

FIGURE 2/Q.706

Probability of message signal unit delayed more than T_x

4.2.4 Examples

Assuming the traffic models given in Table 3, examples of queueing delays are calculated as listed in Table 4.

The values in the corresponding figures have been calculated using a MSU error rate of 10^{-3} which approximates to a 10^{-5} bit error probability. In many cases, the link error probability of signalling data links (terrestrial and satellite) is better than 10^{-7}, at which rate the effects on queueing delays are minimal.

NOTE – The values in the Table 3 were determined based on TUP messages. With the increase of the effective message length, using ISUP and TC, these values may be expected to be increased during the course of further study.

TABLEAU 3/Q.706

Traffic model

Model	A	B	
Message length (bits)	120	104	304
Percent	100	92	8
Mean message length (bits)	120	120	
k_1	1.0	1.2	
k_2	1.0	1.9	
k_3	1.0	3.8	

TABLE 4/Q.706

List of examples

Figure	Error control	Queueing delay	Disturbance	Model
3	Basic/PCR	Mean	Absence	A and B
4	Basic/PCR	Standard deviation	Absence	A and B
5	Basic	Mean	Presence	A
6	Basic	Standard deviation	Presence	A
7	PCR	Mean	Presence	A
8	PCR	Standard deviation	Presence	A

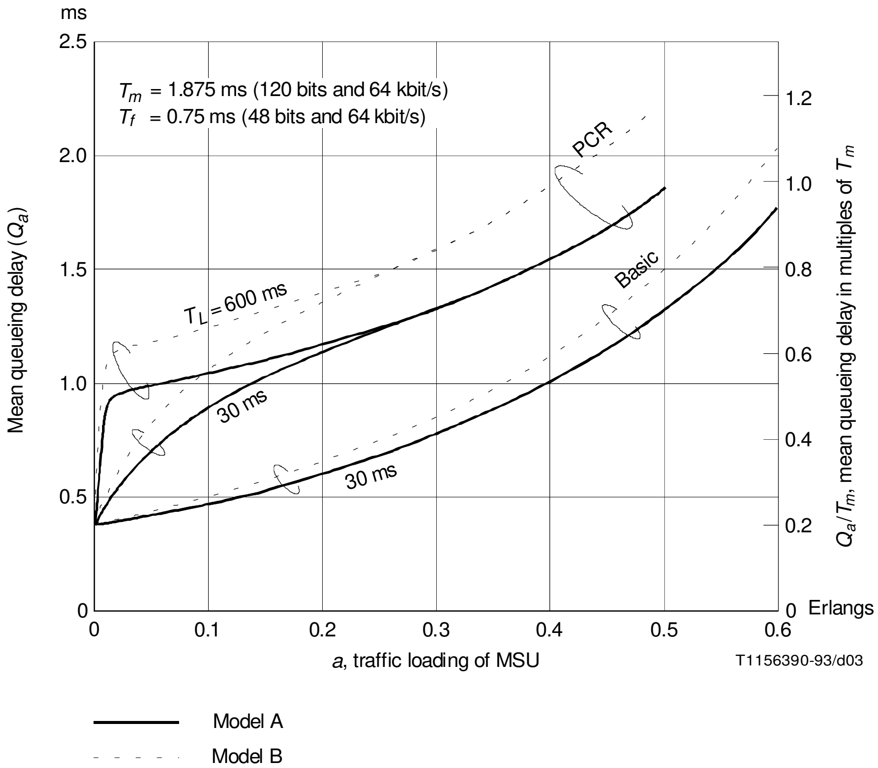


FIGURE 3/Q.706

Mean queueing delay of each channel of traffic in absence of disturbance

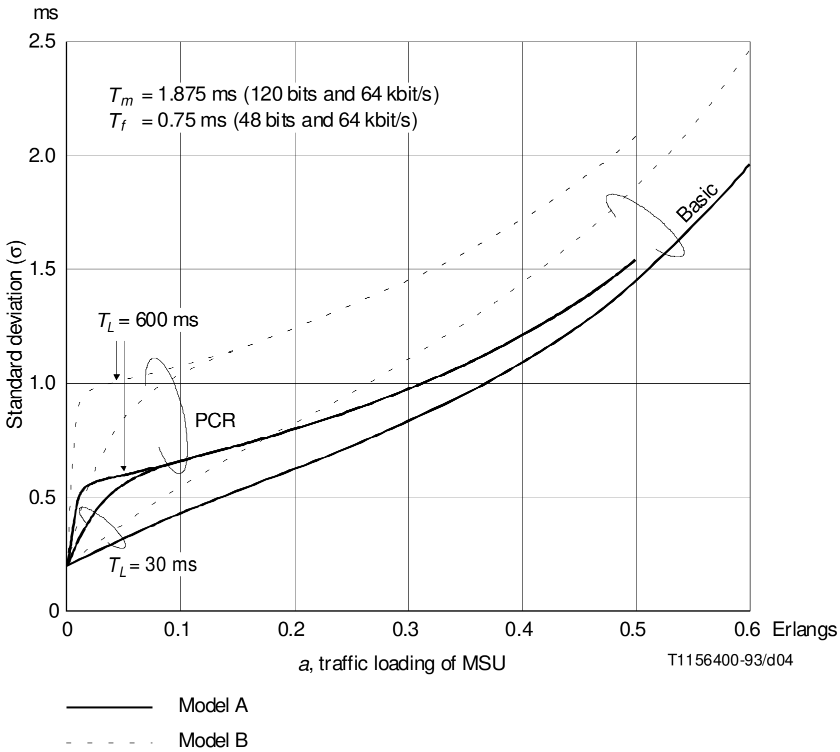


FIGURE 4/Q.706

Standard deviation of queueing delay of each channel of traffic in absence of disturbance

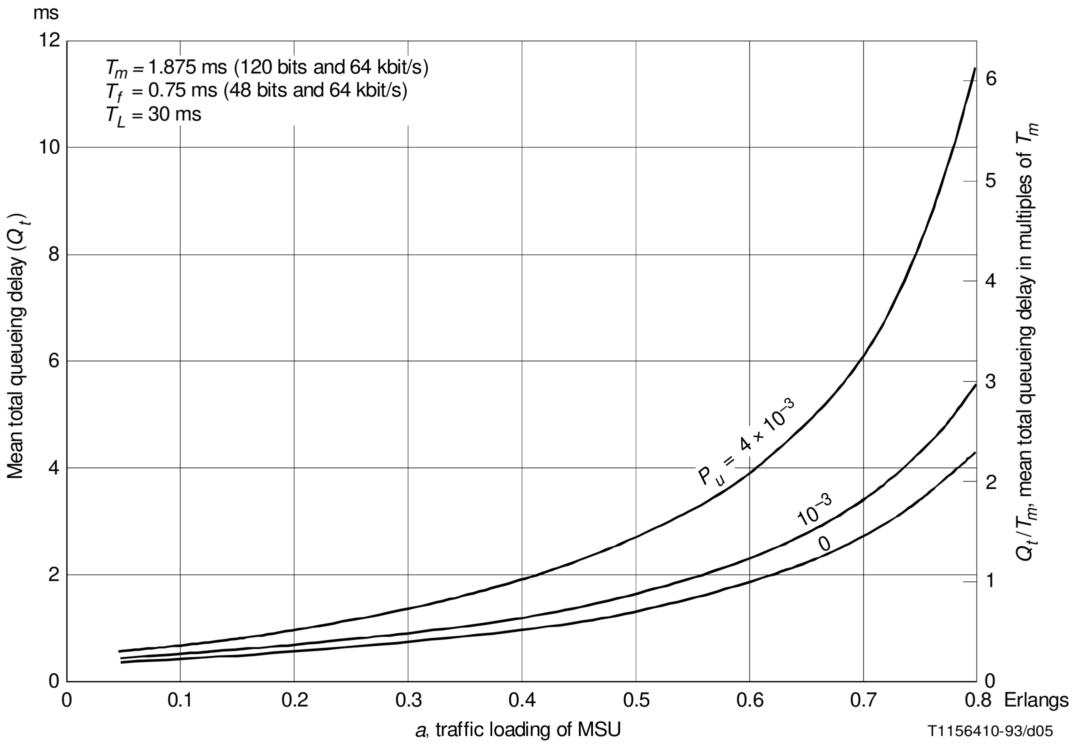


FIGURE 5/Q.706

**Mean total queueing delay of each channel of traffic –
Basic error correction method**

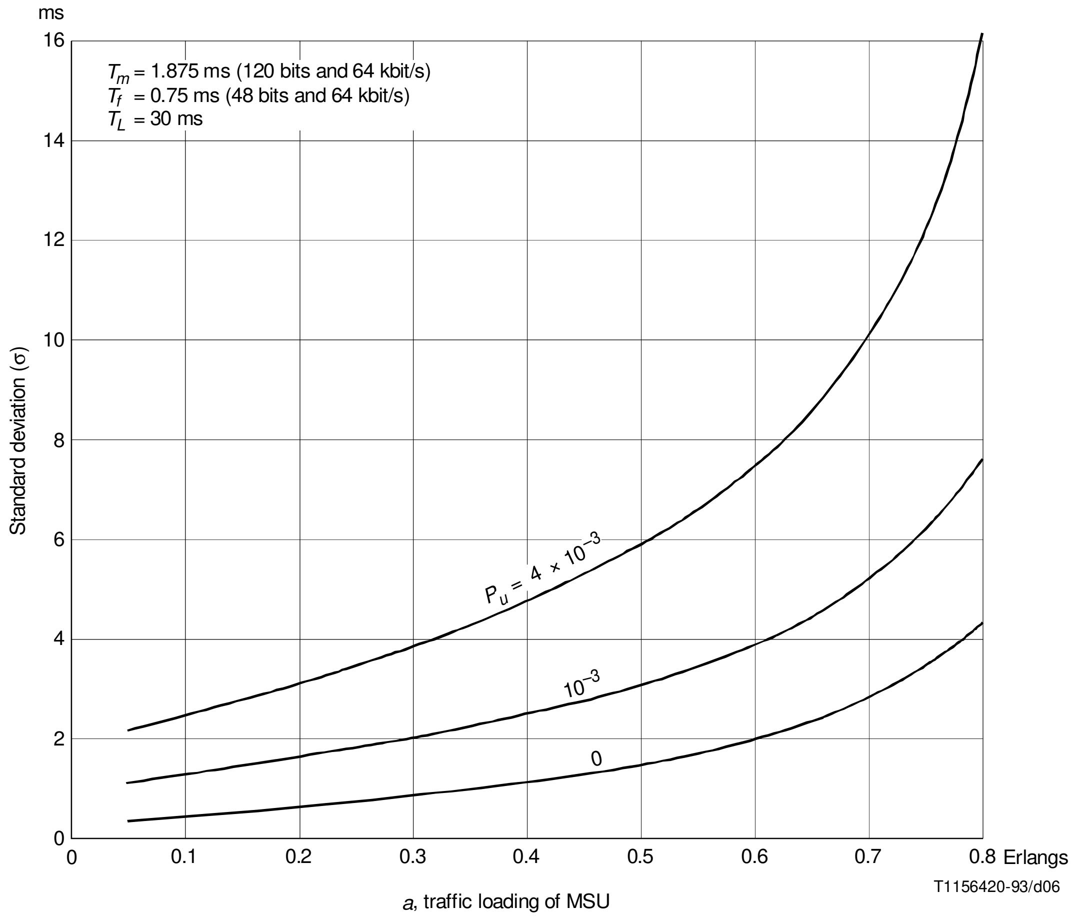


FIGURE 6/Q.706

Standard deviation of queueing delay of each channel of traffic – Basic error correction method

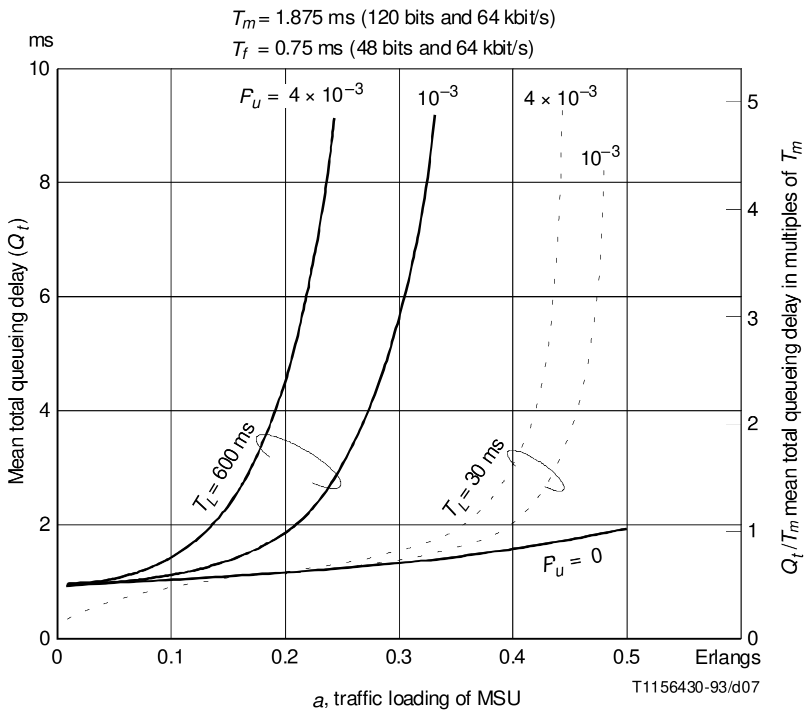


FIGURE 7/Q.706

Mean total queueing delay of each channel of traffic – Preventive cyclic retransmission error correction method

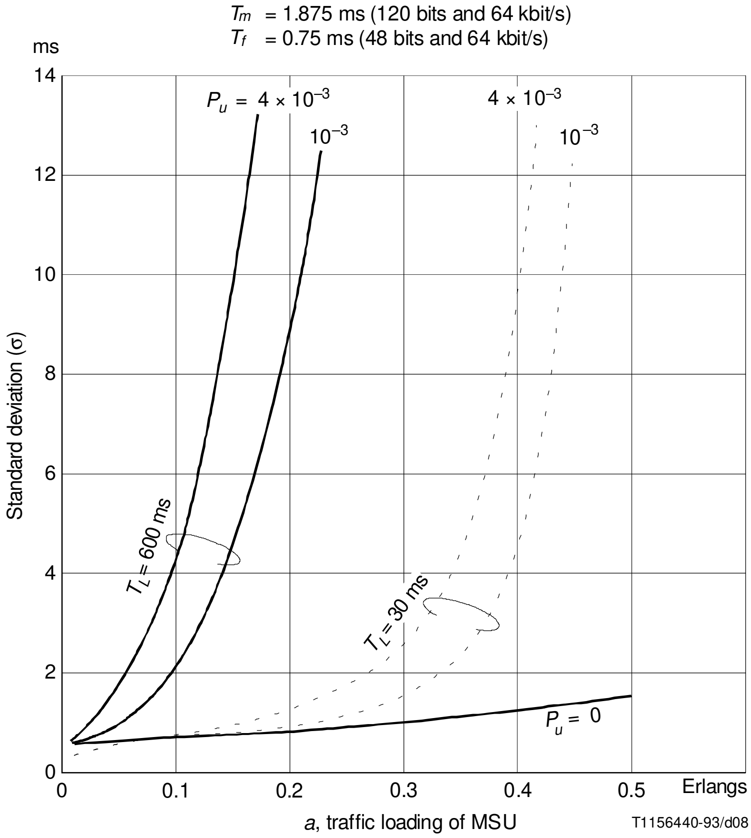


FIGURE 8/Q.706

Standard deviation of queueing delay of each channel of traffic – Preventive cyclic retransmission error correction method

4.3 Message transfer times

Within a signalling relation, the MTP transports messages from the originating User Part to the User Part of destination, using several signalling paths. The overall message transfer time needed depends on the message transfer time components a) to d) (listed below) involved in each signalling path.

4.3.1 Message transfer time components and functional reference points

A signalling path may include the following functional signalling network components and transfer time components.

a) MTP sending function at the point of origin which includes queueing delay (see Figure 9).

b) Signalling transfer point function which includes queueing delay (see Figure 10).

c) MTP receiving function at the point of destination (see Figure 11).

d) Signalling data link propagation time (see Figure 12).

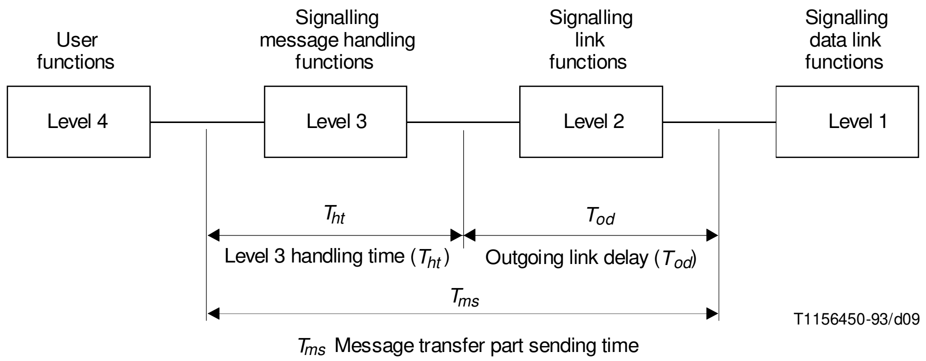


FIGURE 9/Q.706

Functional diagram indicating the components of the message transfer part sending time

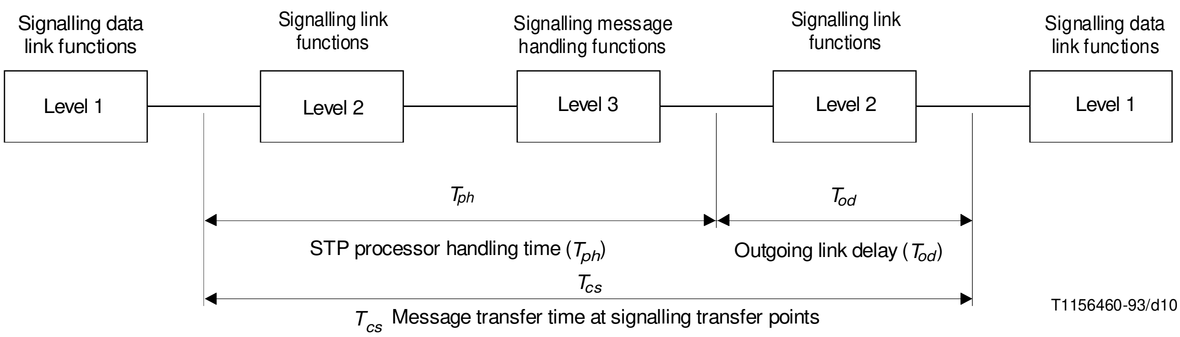


FIGURE 10/Q.706

Functional diagram indicating the components of the message transfer time at signalling transfer points

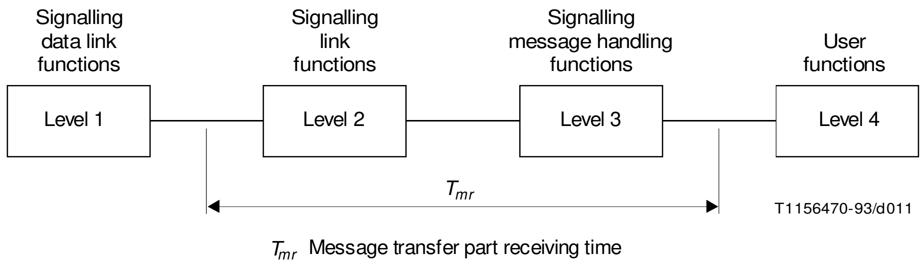


FIGURE 11/Q.706

Functional diagram of the message transfer part receiving time (T_{mr})

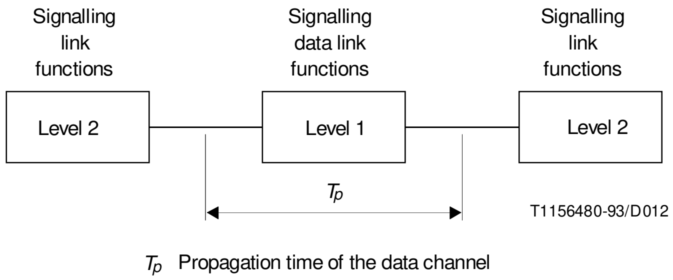


FIGURE 12/Q.706

Functional diagram for the propagation time (T_p)

4.3.2 Definitions

For the purposes of this Recommendation, the following definitions apply:

4.3.2.1 MTP sending time T_{ms}: T_{ms} is the period which starts when the last bit of the message has left the User Part and ends when the last bit of the signal unit enters the signalling data link for the first time. It includes the queueing delay in the absence of disturbances, the transfer time from level 4 to level 3, the handling time at level 3, the transfer time from level 3 to level 2, and the handling time in level 2.

4.3.2.2 message transfer time at signalling transfer points T_{cs}: T_{cs} is the period which starts when the last bit of the signal unit leaves the incoming signalling data link and ends when the last bit of the signal unit enters the outgoing signalling data link for the first time. It also includes the queueing delay in the absence of disturbances but not the additional queueing delay caused by retransmission.

4.3.2.3 MTP receiving time T_{mr}: T_{mr} is the period which starts when the last bit of the signal unit leaves the signalling data link and ends when the last bit of the message has entered the User Part. It includes the handling time in level 2, the transfer time from level 2 to level 3, the handling time in level 3 and the transfer time from level 3 to level 4.

4.3.2.4 data channel propagation time T_p: T_p is the period which starts when the last bit of the signal unit has entered the data channel at the sending side and ends when the last bit of the signal unit leaves the data channel at the receiving end irrespective of whether the signal unit is disturbed or not.

4.3.2.5 outgoing link delay T_{od}: T_{od} is the period which starts when the last bit of the message signal unit enters the level 2 transmission buffer and ends when the last bit of the message signal unit enters the outgoing signalling data link. It includes the level 2 queueing delay in the absence of disturbances and the emission time. The emission time starts when the first bit of the message signal unit enters the outgoing signalling data link and ends when the last bit of the message signal unit enters the outgoing signalling data link.

4.3.2.6 level 3 handling time T_{ht}: T_{ht} is the period which starts when the last bit of the message signal unit has left the User Part and ends when the last bit of the message signal unit enters the level 2 transmission buffer. It includes the transfer time from level 4 to level 3, the handling time at level 3 and the transfer time from level 3 to level 2. It does not include the outgoing link delay.

4.3.2.7 STP processor handling time T_{ph}: T_{ph} is the period which starts when the last bit of the message signal unit leaves the incoming signalling data link and ends when the last bit of the message signal unit enters the level 2 transmission buffer associated with the outgoing signalling data link. It does not include the outgoing link delay.

4.3.3 overall message transfer times: The overall message transfer time T_O refers to a signalling relation. T_O starts when the message has left the user part (level 4) at the point of origin and ends when the message has entered the user part (level 4) at the point of destination.

The definition of the overall message transfer time and the definitions of the individual message transfer time components give rise to the following relationships:

a) In the absence of disturbances

$$T_{oa} = T_{ms} + \sum_{i=1}^{n+1} T_{pi} + \sum_{i=1}^{n} T_{csi} + T_{mr}$$

b) In the presence of disturbances

$$T_o = T_{oa} + \Sigma(Q_t - Q_a)$$

Here

T_{oa} Overall message transfer time in the absence of disturbances

T_{ms} MTP sending time

T_{mr} MTP receiving time

T_{cs} Message transfer time at signalling transfer points

n Number of STPs involved

T_p Data channel propagation time

T_o Overall message transfer time in the presence of disturbances

Q_t Total queueing delay (see 4.2)

Q_a Queueing delay in the absence of disturbances (see 4.2)

NOTE – For $\Sigma(Q_t - Q_a)$, all signalling points in the signalling relation must be taken into account.

4.4 Error control

During transmission, the signal units are subject to disturbances which could lead to errors in the signalling information. The error control reduces the effects of these disturbances to an acceptable value.

Error control is based on error detection by redundant coding and on error correction by retransmission. Redundant coding is performed by generation of 16 check bits per signal unit based on the polynomial described in 4.2/Q.703. Moreover, the error control must not introduce loss, duplication or missequencing of messages on an individual signalling link.

However, abnormal situations may occur in a signalling relation, which are caused by failures, so that the error control for the signalling link involved cannot ensure the correct message sequence.

4.5 Security arrangements

The security arrangements have an essential influence on the observance of the availability requirements listed in 1.1 for a signalling relation.

In the case of SS No. 7, the security arrangements are mainly formed by redundancy in conjunction with changeover.

4.5.1 Types of security arrangements

In general, a distinction has to be made between security arrangements for the individual components of the signalling network and security arrangements for the signalling relation. Within a signalling network, any security arrangement may be used, but it must be ensured that the availability requirements are met.

4.5.1.1 Security arrangements for the components of the signalling network

Network components, which form a signalling path when being interconnected, either have constructional security arrangements which exist from the very beginning (e.g. replication of the controls at the exchanges and signalling transfer points) or can be replicated, if need be (e.g. signalling data links). For security reasons, however, replication of signalling data links is effected only if the replicated links are independent of one another (e.g. multipath routing). In the case of availability calculations for a signalling path set, special care has to be taken that the individual signalling links are independent of one another.

4.5.1.2 Security arrangements for signalling relations

In quasi-associated signalling networks where several signalling links in tandem serve one signalling relation, the security arrangements for the network components, as a rule, do not ensure sufficient availability of the signalling relation. Appropriate security arrangements must therefore be made for the signalling relations by the provision of redundant signalling path sets, which have likewise to be independent of one another.

4.5.2 Security requirements

A signalling network has to be provided with sufficient redundancy and capacity so that the signalling network performance is satisfactory.

4.5.3 Time to initiate changeover

If individual signalling data links fail, due to excessive error rates, changeover is initiated by signal unit error monitoring (see 8/Q.703). With signal unit error monitoring, the time between the occurrence of the failure and the initiation of changeover is dependent on the message error rate (a complete interruption will result in an error rate equal to 1).

Changeover leads to substantial additional queueing delays. To keep the latter as short as possible, the signalling traffic affected by an outage is reduced to a minimum by the use of load sharing on all existing signalling links.

4.5.4 Changeover performance times

There are two performance times associated with link changeover. Both times are maximum time values (not normal values). They are defined to be the point at which 95% of the events occur within the recommended performance time at a signalling point traffic load that is 30% above normal.

The performance times are measured from outside the signalling point.

4.5.4.1 Failure response time

This time describes the time taken by a signalling point to recognize that a changeover is needed for a signalling link. This time begins when the signalling link is unavailable, and ends when the signalling point sends a changeover (or emergency changeover) order to the remote signalling point. A link is unavailable when a signalling unit with status indication out of service (SIOS) or processor outage (SIPO) is sent or received on the link.

Failure response time (maximum permissible): 500 ms.

4.5.4.2 Answer time to changeover order

This time describes the time taken by a signalling point to answer a changeover (or emergency changeover) order. This time begins when the signalling point receives a changeover (or emergency changeover) order message, and ends when the signalling point sends a changeover (or emergency changeover) acknowledgement message.

Answer time to changeover order (maximum permissible): 300 ms.

4.6 Failures

4.6.1 Link failures

During transmission, the messages may be subject to disturbances. A measure of the quality of the signalling data link is its signal unit error rate.

Signal unit error monitoring initiates the changeover at a signal unit error rate of about $4 \cdot 10^{-3}$.

The error rate, which SS No. 7 has to cope with, represents a parameter of decisive influence on its efficiency.

As a result of error correction by retransmission, a high error rate causes frequent retransmission of the message signal units and thus long queueing delays.

4.6.2 Failures in signalling points

Needs further study.

4.7 Priorities

Priorities resulting from the meaning of the individual signals are not envisaged. Basically, the principle “first-in-first-out” applies.

Although the service indicator offers the possibility of determining different priorities on a user basis, such user priorities are not yet foreseen.

Transmission priorities are determined by MTP functions. They are solely dependent on the present state of the MTP and completely independent of the meaning of the signals (see 11/Q.703).

5 Estimates for message transfer times

The estimates must take account of

- the length of the signal unit;
- the signalling traffic load;
- the signalling bit rate;
- the signalling loop delay (terrestrial or satellite);
- the error correction method used;
- the bit error rate.

The estimates are presented in the form of

- mean values,
- 95% level values.

The figures are related to 64 kbit/s signalling bit rate. The normal signalling traffic load is that load for which the signalling transfer point is engineered. A mean value of 0.2 erlang per signalling links assumed.

5.1 Estimate for T_{cs}

The estimates for T_{cs} for a signalling transfer point are given in Table 5.

TABLE 5/Q.706

Message transfer time at an STP (T_{cs})

STP signalling traffic load	(T_{cs}) ms	
	Mean	95%
Normal	20	40
+ 15%	40	80
+ 30%	100	200
NOTE – The values in the table were determined based on TUP messages.		

The message length distribution is as given in Table 3.

For the User Parts defined later than the TUP, larger message lengths are typical. For these larger message lengths, the mean values for T_{cs} are not given as a whole, but can be calculated by adding the mean values of T_{od} and T_{ph}.

5.2 Calculation for T_{od}

The outgoing link delay T_{od} is calculated with the parameters:

- loop delay (terrestrial or satellite);
- correction method (BEC or PCR);
- disturbances (message errors);
- link load (0.2 or 0.4 erlang);
- message length (15 ... 279 bytes).

5.2.1 Assumptions

5.2.1.1 Disturbances

The outgoing link delay T_{od} is defined as not including retransmissions due to disturbances. However, the BEC and the PCR correction methods have different effects when disturbances are present.

Two rates of disturbances are considered:

- bit error probability of 10^{-5} (which relates to the assumption of 10^{-3} message error rate probability used in Figures 5 through 8 for message lengths of 120 bits); and
- bit error probability of 10^{-7}.

The first rate of 10^{-5} serves to match previous graphs (Figures 5 through 8) in 4.2.4. The second rate of 10^{-7} is more representative of signalling data links designed according to Recommendation G.821 and its associated apportionment rules.

5.2.1.2 Emission time

The assumed channel bit rate is 64 kbit/s. Therefore the emission time is T_m = n × 0.125 ms, where n is the number of bytes in an MSU.

5.2.1.3 Loop delay

The signalling loop propagation time, including processing time in the signalling terminal, T_L, is assumed to be

– 30 ms for terrestrial links;

– 600 ms for satellite links.

5.2.1.4 Link load

The traffic loading is assumed to be 0.2 erlang for normal load and 0.4 erlang for the load after the changeover of a parallel link.

5.2.1.5 Queueing delay

The queueing delay formulae of Table 2 are used for BEC and PCR error correction in the presence and absence of disturbances. These formulae are basically derived from the *M*/*G*/1 queue with priority assignment (see 4.2.1).

The length of the MSUs ranges from 9 bytes to 279 bytes. Representative mean message lengths of 15, 23 and 50 bytes have been used with their lengths following a negative exponential distribution. This simplifies the queueing system to *M*/*M*/1. When a mean message length of 279 bytes is used, this implies a constant length which simplifies the queueing system to *M*/*D*/1 (deterministic service time distribution).

For a mean MSU length of 140 bytes, the delay time values are between those of the *M*/*M*/1 (worst case) and the *M*/*D*/1 (best case) queueing systems. The delay time is determined by adding 2/3 of the *M*/*M*/1 results and 1/3 of the *M*/*D*/1 results for 140 bytes mean length MSUs.

For calculations of k_1 ... k_3 moments. See Annex B.1.

5.2.1.6 95% values

The 95% values of the queueing delay times were calculated approximately using the formula given in 4.2.3. For details, see Annex B.2.

5.2.1.7 Outgoing link delay T_{od}

Outgoing link delay T_{od} is the sum of queueing delay and emission time for mean and 95% values.

5.2.2 Results for T_{od} with error rate of 10^{-5}

Tables 6 and 7 show the values for outgoing link delay T_{od}. Figures 13 through 16 show this data graphically.

NOTE – P_b = 0/1 e-5 means that the lines for P_b = 0 and P_b = 1.e-5 are almost identical, e-5 means 10^{-5}.

TABLE 6/Q.706

Outgoing link delay T_{od} with basic error correction method

a [Erl]	T_L [ms]	Disturbance	Value	Outgoing link delay (ms) MSU – Length (Bytes) 15	23	50	140	279
0.2	30	No	Mean	2.7	4.0	8.3	21.5	39.6
			95%	9.3	14.0	30.1	66.0	61.5
		Yes	Mean	2.8	4.1	8.4	21.9	40.4
			95%	10.8	15.4	31.4	68.0	64.8
	600	No	Mean	2.7	4.0	8.3	21.5	39.6
			95%	9.3	14.0	30.1	66.0	61.5
		Yes	Mean	29.6	31.2	36.9	55.0	80.3
			95%	248.4	254.2	275.0	329.4	363.8
0.4	30	No	Mean	3.5	5.2	10.8	27.6	46.9
			95%	12.2	18.6	40.0	88.7	87.1
		Yes	Mean	3.8	5.4	11.2	28.3	48.1
			95%	14.3	20.4	41.7	91.4	91.3
	600	No	Mean	3.5	5.2	10.8	27.6	46.9
			95%	12.2	18.6	40.0	88.7	87.1
		Yes	Mean	86.3	88.5	96.9	121.9	152.0
			95%	490.1	496.4	521.2	586.6	626.9

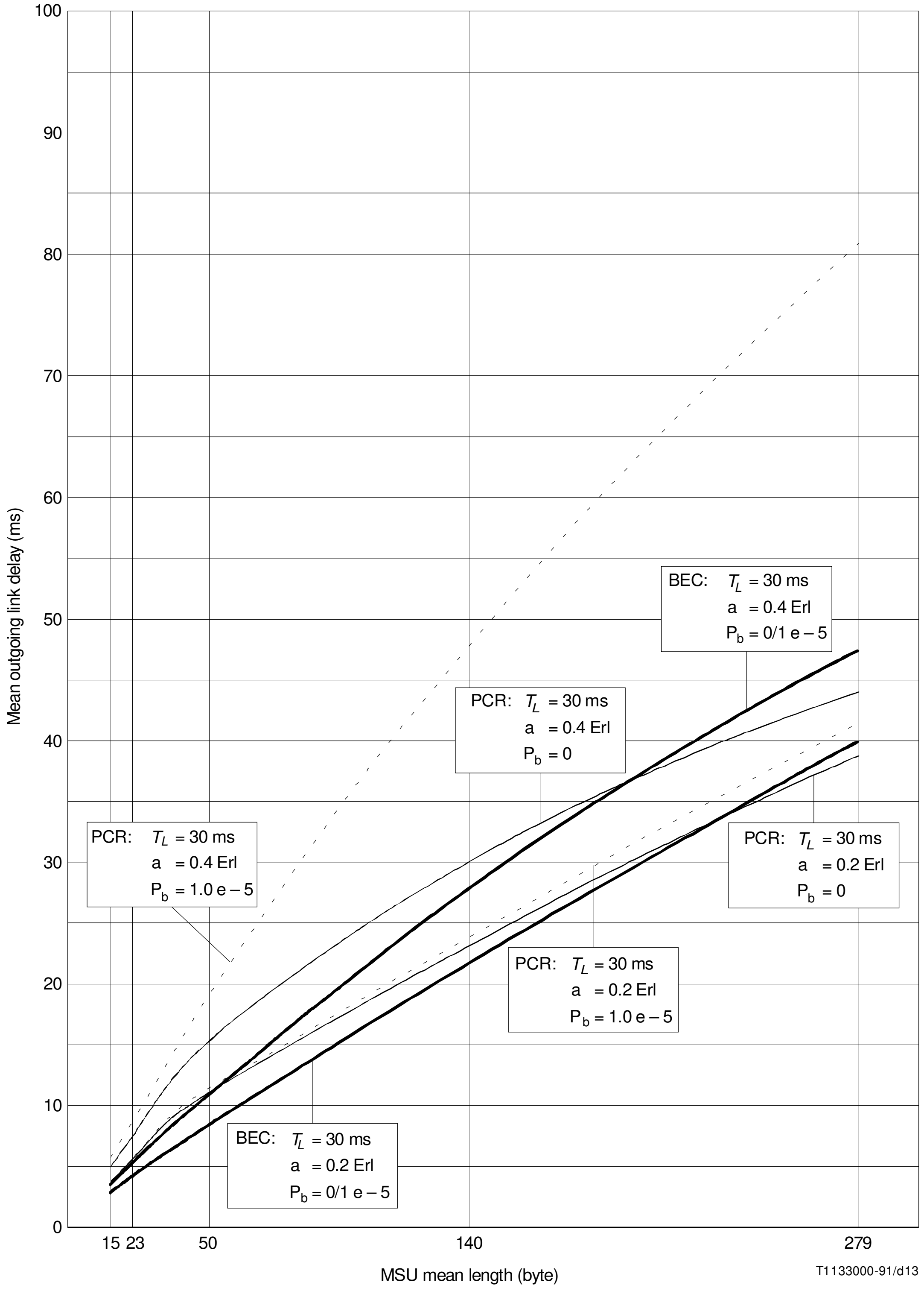
a Traffic loading by MSUs (excluding retransmission)

T_L Signalling link loop propagation time including processing time in signalling terminal mean bit error probability $< 10^{-5}$ in the presence of disturbance.

TABLE 7/Q.706

Outgoing link delay T_{od} with preventive cyclic retransmission method

a [Erl]	T_L [ms]	Disturbance	Value	Outgoing link delay (ms)				
				MSU – Length (Bytes)				
				15	23	50	140	279
0.2	30	No	Mean	4.2	6.4	11.3	23.1	38.7
			95%	12.5	18.9	38.1	71.1	58.6
		Yes	Mean	4.2	6.2	11.4	24.0	41.3
			95%	12.8	19.3	39.5	80.4	84.5
	600	No	Mean	4.2	6.5	14.1	35.7	56.0
			95%	12.6	19.4	42.2	93.1	86.2
		Yes	Mean	5.0	7.4	15.5	39.3	63.0
			95%	27.8	34.9	60.3	127.2	149.0
0.4	30	No	Mean	5.0	7.6	15.3	29.9	43.8
			95%	15.0	22.9	48.3	93.8	79.8
		Yes	Mean	5.6	8.7	18.9	47.5	81.1
			95%	26.3	42.5	106.2	310.9	448.2
	600	No	Mean	5.0	7.7	16.7	41.8	63.9
			95%	15.0	23.0	50.0	111.4	108.9
		Yes	Mean	47.2	55.1	84.8	183.5	282.5
			95%	379.7	422.7	586.2	1103	1470



BEC Basic error correction method / PCR = preventive cyclic retransmission method
T_L Signalling loop propagation time including processing time in signalling terminal
a Traffic load by MSUs excluding retransmission
P_b Bit error probability

FIGURE 13/Q.706

Mean outgoing link delay – T_L = 30 ms

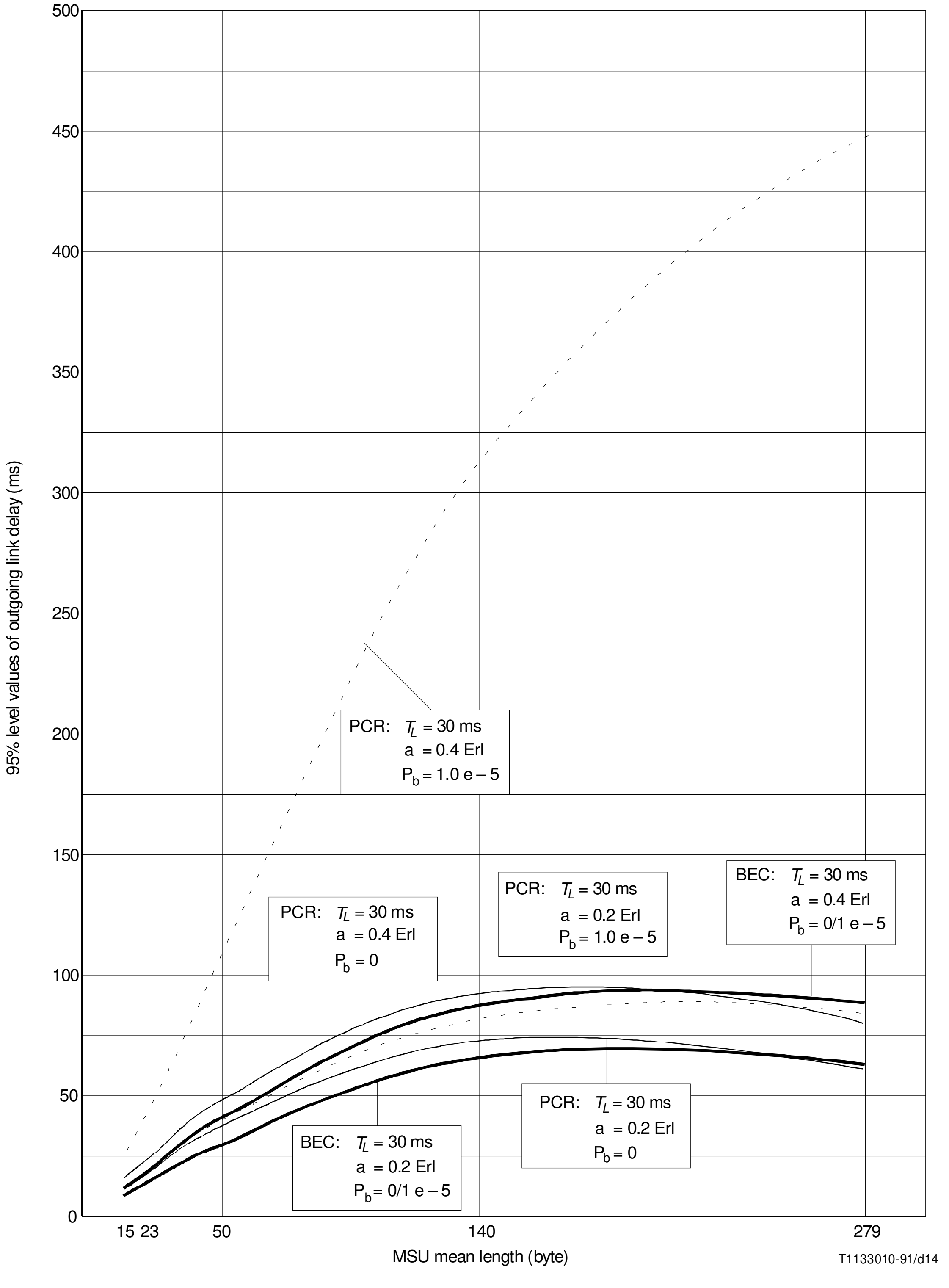


FIGURE 14/Q.706

95% level value of outgoing link delay – T_L = 30 ms

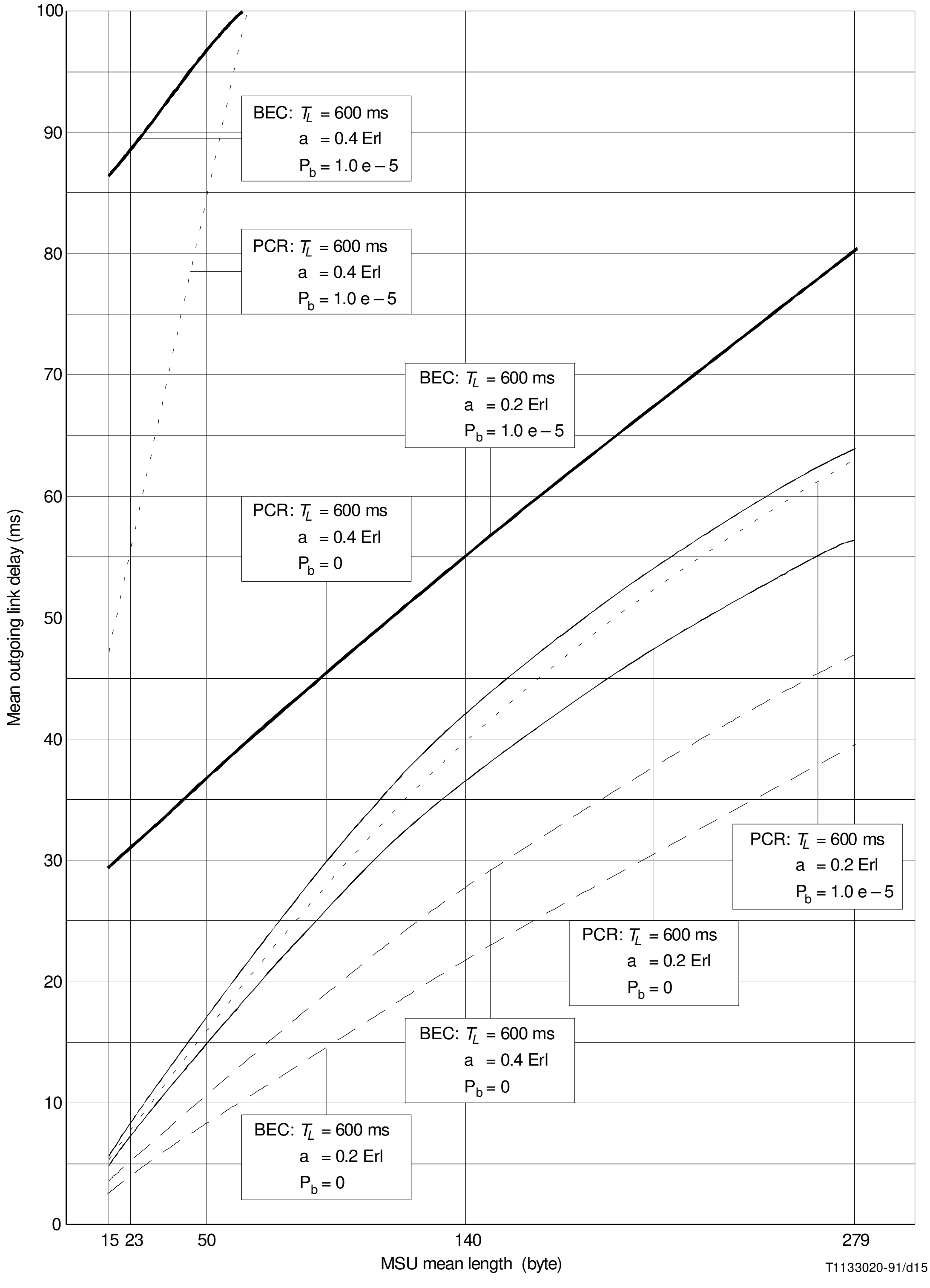


FIGURE 15/Q.706

Mean outgoing link delay – T_L = 600 ms

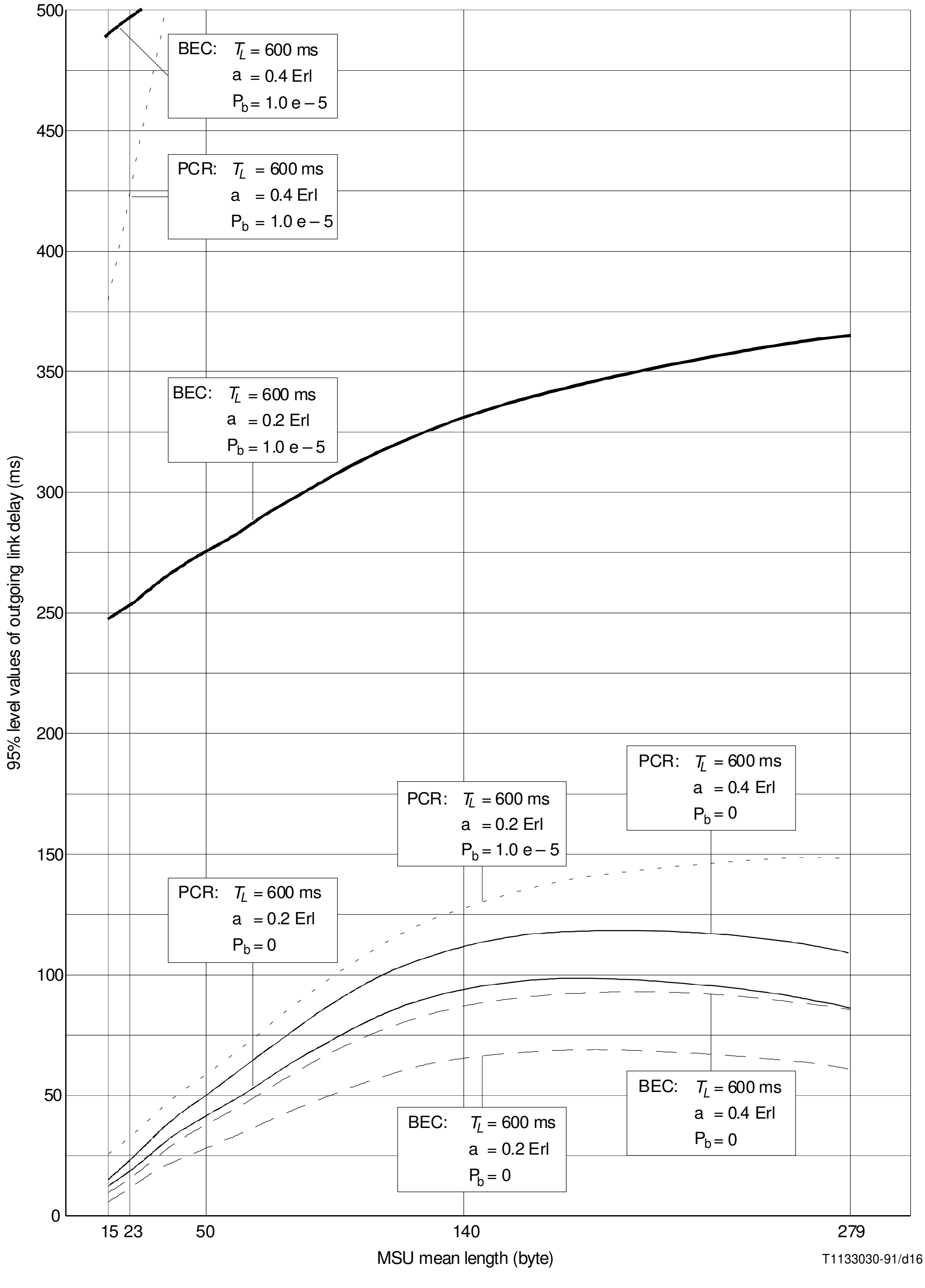


FIGURE 16/Q.706

95% level value of outgoing link delay – T_L = 600 ms

5.2.3 Discussion of results with bit error rate of 10^{-5}

Some conclusions can be drawn from Tables 6 and 7 and Figures 13 through 16.

Furthermore, the curves for $P_b = 0$ in Figures 13 and 15 closely approximate the results for $P_b = 10^{-7}$ (see Tables 9 and 10).

5.2.3.1 Terrestrial links

- normally only BEC is used on terrestrial links;
- there is almost no influence on the delay by the disturbances assumed;
- the mean values for T_{od} rise up to 40 to 50 ms for long messages;
- the 95% values for T_{od} rise up to 100 ms (the slight decrease for messages near 279 bytes long may be explained by the different length distributions – see 5.2.1.5.);
- the values for PCR-method given in Figures 13 and 14 are theoretical only, but they do indicate the limitations of the PCR-method for high loads (0.4 erlang).

For a mean MSU length of 140 bytes the delay time values are between those of the *M*/*M*/1 queueing system (worst case) and the *M*/*D*/1 queueing system (best case). Therefore, those delay time values are calculated approximately by a superposition of the *M*/*M*/1 results (weight 2/3) and the results of *M*/*D*/1 (weight 1/3) both for a mean MSU length of 140 bytes.

For the calculation of k_1 ... k_3 moment see Annex B.1.

5.2.3.2 Satellite links

- Normally the PCR-method is used for satellite links.
- The PCR-method works well provided that the link load is not high. The mean outgoing link delay (see Figure 15) shows good performance for the PCR-method at 0.2 erlang, with disturbances and without disturbances. T_{od} rises up to 65 ms. The BEC-method with disturbances rises to 80 ms at 0.2 erlang.
- However, with a link load of 0.4 erlang, the PCR-method in the presence of disturbances has no advantages left unless the link bit error rates is lower than the assumed 10^{-5}.

5.2.4 Results for T_{od} with bit error rate of 10^{-7}

The very high values for outgoing link delay (T_{od}) calculated in 5.2.3 should be avoided. Possibilities for reducing the values are

- reducing the link load much below 0.4 erlang;
- using links with low bit error rates.

The following calculations show that at 10^{-7}, the effect on T_{od} is very low.

The MSU error probability shown in Table 8 is calculated from the bit error rate from the following formula

$$P_u\,(\mathrm{n}) = 8 \times \mathrm{n} \times 10^{-7}$$

where n is the mean message length in bytes.

TABLE 8/Q.706

Mean MSU error probability dependant on the mean MSU length

MSU length n (bytes)	15	23	50	140	279
MSU error probability P_u (n) [%]	0.0012	0.0018	0.004	0.0112	0.0223

Tables 9 and 10 show the values for outgoing link delay T_{od} for bit error probability of 10^{-7}.

5.2.4.1 Terrestrial links

The queueing delay values are slightly lower when the link bit error rate is improved from 10^{-5} to 10^{-7}.

5.2.4.2 Satellite links

The queueing delay values are considerably lower when the link bit error rate is improved from 10^{-5} to 10^{-7}.

TABLE 9/Q.706

Outgoing link delay T_{od} with basic error correction method

a [Erl]	T_L [ms]	Disturbance	Value	Outgoing link delay (ms)				
				MSU – Length (Bytes)				
				15	23	50	140	279
0.2	30	No	Mean	2.7	4.0	8.2	21.5	39.6
			95%	9.3	14.0	30.1	66.0	61.5
		Yes	Mean	2.7	4.0	8.2	21.5	39.6
			95%	9.3	14.1	30.1	66.0	61.5
	600	No	Mean	2.7	4.0	8.2	21.5	39.6
			95%	9.3	14.0	30.1	66.0	61.5
		Yes	Mean	3.0	4.3	8.5	21.9	40.1
			95%	28.9	32.7	46.0	79.2	76.9
0.4	30	No	Mean	3.5	5.2	10.8	27.6	46.9
			95%	12.2	18.6	40.0	88.7	87.1
		Yes	Mean	3.5	5.2	10.8	27.6	46.9
			95%	12.2	18.6	40.0	88.7	87.1
	600	No	Mean	3.5	5.2	10.8	27.6	46.9
			95%	12.2	18.6	40.0	88.7	87.1
		Yes	Mean	4.3	6.0	11.6	28.5	47.9
			95%	44.0	48.4	64.5	107.4	106.9

a Traffic loading by MSUs (excluding retransmission)

T_L Signalling loop propagation time including processing time in signalling terminal mean bit error probability $< 10^{-7}$ in the presence of disturbance.

TABLE 10/Q.706

Outgoing link delay T_{od} with preventive cyclic retransmission method

a [Erl]	T_L [ms]	Disturbance	Value	Outgoing link delay (ms)				
				MSU – Length (Bytes)				
				15	23	50	140	279
0.2	30	No	Mean	4.2	6.1	11.3	23.1	38.7
			95%	12.5	18.9	38.0	71.1	58.6
		Yes	Mean	4.2	6.2	11.3	23.1	38.7
			95%	12.8	18.9	38.0	71.3	59.0
	600	No	Mean	4.2	6.5	14.1	35.7	56.0
			95%	12.6	19.4	42.2	93.1	86.2
		Yes	Mean	4.2	6.5	14.1	35.8	56.1
			95%	13.0	19.7	42.5	93.7	87.4
0.4	30	No	Mean	5.0	7.6	15.2	29.9	43.8
			95%	15.0	22.9	48.2	93.8	79.8
		Yes	Mean	5.0	7.6	15.3	30.1	44.2
			95%	15.2	23.3	49.7	101.0	96.1
	600	No	Mean	5.0	7.7	16.7	41.8	63.9
			95%	15.0	23.0	50.0	111.4	108.9
		Yes	Mean	5.3	8.0	17.1	42.8	65.3
			95%	30.2	38.1	67.1	141.5	153.9

5.2.5 Conclusions

The results of 5.2.3 and 5.2.4 illustrate that satellite links need to be operated at a bit error rate lower than 10^{-5}, such as 10^{-7}, for acceptable operation when using long message lengths and/or a link load higher than 0.2 erlang. In practice, most current satellite links operate, and future links will be designed to operate, at a bit error rate at or below the rate of 10^{-7} specified in Recommendation G.821.

5.3 Estimates for STP processor handling time T_{ph}

The delay times for T_{ph} are implementation dependant. The implementation hardware depends on the state of the technology at the time it was developed. Advances in technology may reduce the delay values presented in this subclause.

The proposed values for T_{ph} shown in Table 11 relate to hardware of the *Red Book/Blue Book* time frame.

The overall mean delay in an STP can be estimated by adding the mean values of T_{od} and T_{ph}. However, the overall 95% delay in an STP cannot be estimated by a simple summation of the 95% values for T_{od} and T_{ph}.

TABLE 11/Q.706

STP processor handling time T_{ph}

Processor load	Delay value	Mean message SU length			
		23 bytes	50 bytes	140 bytes	279 bytes (Note)
Normal	Mean	19	22	33	55
	95%	35	40	50	75
+ 30%	Mean	60	70	100	160
	95%	120	140	200	320
NOTE – The MSU size is fixed in this case at 279 bytes.					

6 Performance under adverse conditions

6.1 Adverse conditions

Needs further study.

6.2 Influence of adverse conditions

Needs further study.

Annex A

Computation of transmission delays

(This annex forms an integral part of this Recommendation)

The formula to compute transmission delay due to transmission through terrestrial links (assuming the delay at the repeaters is negligible) is

$$D_T = D_P * L$$

The formula to compute transmission delay due to transmission through satellite links for a single hop is:

$$D_{s(min)} = 2 * h * D_P$$

$$D_{s(max)} = 2 * (h + r) * D_P$$

where

D_T is the total delay incurred by terrestrial links;

D_s is the total delay incurred by satellite links;

D_P is the transmission time along link (delay per unit distance);

L is the arc length (distance between stations across the surface of the Earth);

r is the radius of the Earth (6,370 km);

h is the height of satellite above surface of the Earth (35,800 km).

The formula for $D_{s(max)}$ is simplified based on the relative values of r and h given above. It must be noted that a link may not be set up in a straight line. This implies that the terrestrial delay will be larger if a link is not set up in this manner. It is assumed that the delay will be increased by no more than ten per cent if a message must detour from the straight line path to reach its destination.

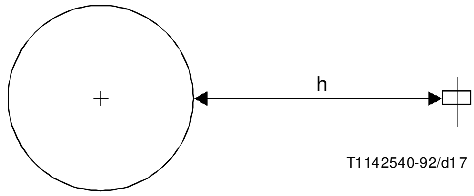


FIGURE A.1/Q.706

Assumed positioning of satellite for $D_{s(min)}$

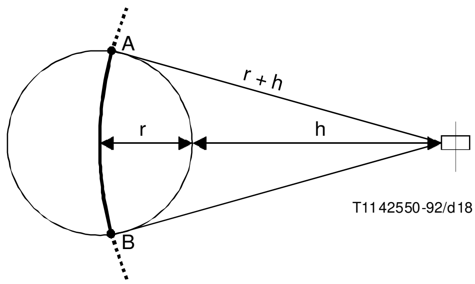


FIGURE A.2/Q.706

Assumed positioning of satellite for $D_{s(max)}$

Table A.1 shows typical link transmission speeds, with repeater spacings and corresponding repeater delays for each method of message transmittal. These constants are used in the equations above for calculating the delays associated with calls of different arc lengths.

TABLE A.1/Q.706

Delay constants

	Transmission speed (km/s)	Transmission delay (ms/km) D_P
Terrestrial satellites	299 793	0.0033
Wire Fibre Radio	209 855 199 802 299 793	0.0048 0.005 0.0033

Annex B

Calculation of Outgoing Link Delay (T_{od})

(This annex forms an integral part of this Recommendation)

B.1 Calculation of the *k*th moments of the MSU emission time

The *k*th moment of the MSU emission time is required for the factors, k_1, k_2 and k_3 in 4.2.2:

$$m_k = \int_{t=0}^{\infty} f^k(t)\, dt$$

f(t) = distribution density function

T constant (= T_m): $f(t) = \delta(t - T_m)$

T negative exponential distributed: $f(t) = \exp(-t / T_m)$

With Laplace-Stiltjes transformation:

$$\int_{t=0}^{\infty} f^k(t)\, dt = (-1)^k \cdot \left. \frac{d^k\, \Phi(s)}{ds^k} \right|_{s = 0}$$

T constant: $\Phi(s) = \exp(-s \cdot T_m)$

so:

2. moment $m_2 = T_m^2$

3. moment $m_3 = T_m^3$

4. moment $m_4 = T_m^4$

T negative exponential distributed: $\Phi(s) = \dfrac{1}{(1 + s \cdot T_m)}$

so:

2. moment $m_2 = 2\, T_m^2$

3. moment $m_3 = 6\, T_m^3$

4. moment $m_4 = 24\, T_m^4$

This results to the following values for the factors k_1, k_2 and k_3 (see 4.2.2):

general:

$$k_1 = \frac{m_2}{T_m^2}$$

$$k_2 = \frac{m_3}{T_m^3}$$

$$k_3 = \frac{m_4}{T_m^4}$$

T constant:

$$k_1 = 1$$

$$k_2 = 1$$

$$k_3 = 1$$

T negative exponential distributed:

$$k_1 = 2$$

$$k_2 = 6$$

$$k_3 = 24$$

B.2 Approximative calculation of the 95% – Values of T_{od}

$$\boxed{T_{od.95\%} = Q_{t.95\%} + T_{m.95\%}}$$

$Q_{t.95\%}$ and $T_{m.95\%}$ are calculated with the help of the approximation in 4.2.3:

$$\boxed{P(> T_{95\%}) \cong \exp\left(-\frac{T_{95\%} - T_{\text{mean}} + \sigma}{\sigma}\right)}$$

$P(T \le T_{95\%}) = 1 - P(T_{95\%})$ with $P(T \le T_{95\%}) = 0.95$

where $T_{95\%} \cong T_{\text{mean}} + 2\sigma$ with T_{mean} = mean value of T

σ = standard deviation of T

This gives:

$$Q_{t.95\%} \cong Q_t + 2\sigma$$

and

$T_{m.95\%} \cong 3T_m$ for mean MSU length 15, 23 or 50 bytes

$T_{m.95\%} \cong 2/3 \times 3T_m + 1/3 \times T_m$

$= 7/3 \times T_m$ for mean MSU length 140 bytes

$T_{m.95\%} = T_m$ for mean MSU length 279 bytes.

Reference

[1] CCITT Recommendation *Error performance on an international digital connection forming part of an integrated services digital network*, Vol. III, Rec. G.821.