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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Quality and availability targets

Error performance of an international digital connection forming part of an integrated services digital network

Reedition of CCITT Recommendation G.821 published in the Blue Book, Fascicle III.5 (1989)

NOTES

1 CCITT Recommendation G.821 was published in Fascicle III.5 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

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

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Recommendation G.821

ERROR PERFORMANCE OF AN INTERNATIONAL DIGITAL CONNECTION FORMING PART OF AN INTEGRATED SERVICES DIGITAL NETWORK

(Geneva, 1980; further amended)

The CCITT,

considering

(a) that services in the future may expect to be based on the concept of an Integrated services digital network (ISDN);

(b) that errors are a major source of degradation in that they affect voice services in terms of distortion of voice, and data type services in terms of lost or inaccurate information or reduced throughout;

(c) that while voice services are likely to predominate, the ISDN is required to transport a wide range of service types and it is therefore desirable to have a unified specification;

(d) that an explanation of network performance objectives and their relationship with design objectives is given in Recommendation G.102,

recommends

that within the following scope and definitions the requirements set out in Table 1/G.821 and subsequent paragraphs should be met.

1 Scope and definitions

1.1 The performance objectives are stated for each direction of a 64 kbit/s circuit-switched connection used for voice traffic or as a "Bearer Channel" for data-type services.

1.2 Recommendation I.325 gives reference configurations for the ISDN connection types listed in Recommendation I.340. In the context of error performance of 64 kbit/s circuit-switched connection types and the allocation of performance to the connection elements, an all digital hypothetical reference configuration (HRX) is given in Figure 1/G.821. It encompasses a total length of 27 500 km and is a derivative of the standard hypothetical reference configuration given in Figure 1/G.801 and of the reference configuration given in Figure 3/I.325.

1.3 The performance objective is stated in terms of **error performance parameters** each of which is defined as follows:

"The percentage of averaging periods each of time interval T_0 during which the bit error ratio (BER) exceeds a threshold value. The percentage is assessed over a much longer time interval T_L" (see Note 3 to Table 1/G.821).

It should be noted that total time (T_L) is split into two parts, namely, time for which the connection is deemed to be available and that time when it is unavailable (see Annex A).

Requirements relating to the permissible percentage of unavailable time will be the subject of a separate Recommendation.

1.4 The following BERs and intervals are used in the statement of objectives:

a) a BER of less than $1 \cdot 10^{-6}$ for $T_0 = 1$ minute;

b) a BER of less than $1 \cdot 10^{-3}$ for $T_0 = 1$ second;

c) zero errors for $T_0 = 1$ second (equivalent to the concept of error free seconds EFS).

These categories equate to those of Table 1/G.821. In assessing these objectives, periods of unavailability are excluded (see Annexes A and B).

1.5 The performance objectives aim to serve two main functions:

a) to give the user of future national and international digital networks an indication as to the expected error performance under real operating conditions, thus facilitating service planning and terminal equipment design;

b) to form the basis upon which performance standards are derived for transmission equipment and systems in an ISDN connection.

1.6 The performance objectives represent a compromise between a desire to meet service needs and a need to realize transmission systems taking into account economic and technical constraints. The performance objectives, although expressed to suit the needs of different services are intended to represent a single level of transmission quality.

The performance objective for degraded minutes [Table 1/G.821 (a)] as stated, is based on an averaging period of one minute. This averaging period and the exclusion of errors occurring within severely errored seconds which occur during this one minute period (see Table 1/G.821, Note 2), may allow connections with frequent burst errors to meet this particular part of the overall objective, but such events will be controlled to a certain extent by the severely errored seconds objective [Table 1/G.821 (b)]. However, there is some doubt as to whether the objectives are adequate for proper operation of real-time video services with relatively long holding times, and this is the subject of further study.

1.7 Since the performance objectives are intended to satisfy the needs of the future digital network it must be recognized that such objectives cannot be readily achieved by all of today's digital equipment and systems. The intent, however, is to establish equipment design objectives that are compatible with the objectives in this Recommendation. These aspects are currently the subject of discussion within the CCITT and CCIR.

It is further urged that all technologies, wherever they appear in the network, should preferably be designed to better standards than those indicated here in order to minimize the possibility of exceeding the end-to-end objectives on significant numbers of real connections.

1.8 The objectives relate to a very long connection and recognizing that a large proportion of real international connections will be shorter, it is expected that a significant proportion of real connections will offer a better performance than the limiting value given in § 2. On the other hand, a small percentage of the connections will be longer and in this case may exceed the allowances outlined in this Recommendation.

Note – Controlled slips, which may be perceived as short bursts of errors, are not included in the calculations of the error performance objectives in this Recommendation. Therefore, users should be aware that error performance measurements which include controlled slip effects may produce poorer performance than would be indicated by this Recommendation. Users are directed to Recommendation G.822, which specifies the controlled slip rate objectives, for guidance in estimating the possible effects on their applications.

1.9 The error performance objectives detailed in §§ 2 and 3 of this Recommendation apply to a 64 kbit/s circuit switched connection (as defined in § 1.2). However, it is recognized that in practical situations these objectives will need to be evaluated from measurements made at higher bit rates.

Therefore, Annex D defines preliminary guidelines for estimating 64 kbit/s error performance parameter information from measurements made at the primary and higher bit rates.

2 Performance objectives

The performance objectives for an international ISDN connection as identified in §§ 1.1 and 1.2 are shown in Table 1/G.821. It is intended that international ISDN connections should meet all of the requirements of Table 1/G.821 concurrently. The connection fails to satisfy the objective if any of the requirements is not met.

3 Allocation of overall objectives

Since the objectives given in § 2 relate to an overall connection it is necessary to sub-divide this to constituent parts. This paragraph outlines the basic principles and strategy for apportioning the performance objectives.

The overall apportionment philosophy involves the use of two slightly different strategies, one applicable to the degraded minutes requirement and the errored seconds requirement [see classifications a), c)] and the other applicable to the severely errored seconds requirement [see classification b)].

TABLE 1/G.821

Error performance objectives for international ISDN connections

Performance classification	Objective (Notes 3, 5)
(a) (Degraded minutes) (Notes 1, 2)	Fewer than 10% of one-minute intervals to have a bit error ratio worse than $1 \cdot 10^{-6}$ (Note 4)
(b) (Severely errored seconds) (Note 1)	Fewer than 0.2% of one-second intervals to have a bit error ratio worse than $1 \cdot 10^{-3}$
(c) (Errored seconds) (Note 1)	Fewer than 8% of one-second intervals to have any errors (equivalent to 92% error-free seconds)

Note 1 – The terms "degraded minutes", "severely errored seconds" and "errored seconds" are used as a convenient and concise performance objective "identifier". Their usage is not intended to imply the acceptability, or otherwise, of this level of performance.

Note 2 – The one-minute intervals mentioned in Table 1/G.821 and in the notes (i.e. the periods for M > 4 in Annex B) are derived by removing unavailable time and severely errored seconds from the total time and then consecutively grouping the remaining seconds into blocks of 60. The basic one-second intervals are derived from a fixed period.

Note 3 – The time interval T_L, over which the percentages are to be assessed has not been specified since the period may depend upon the application. A period of the order of any one month is suggested as a reference.

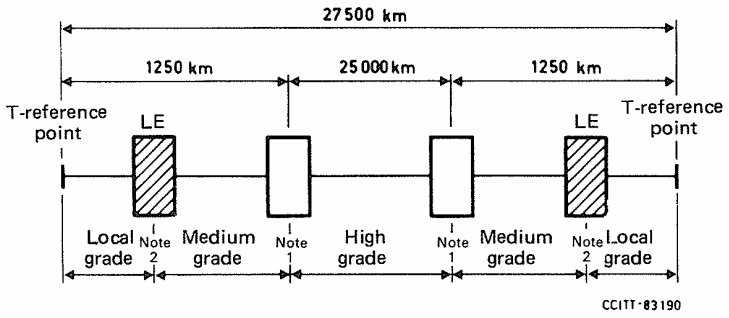
Note 4 – For practical reasons, at 64 kbit/s, a minute containing four errors (equivalent to an error ratio of 1.04×10^{-6}) is not considered degraded. However, this does not imply relaxation of the error ratio objective of $1 \cdot 10^{-6}$.

Note 5 – Annex B illustrates how the overall performance should be assessed.

3.1 *Basic apportionment principles*

Apportionment is based on the assumed use of transmission systems having qualities falling into one of a limited number of different classifications.

Three distinct quality classifications have been identified representative of practical digital transmission circuits and are independent of the transmission systems used. These classifications are termed local grade, medium grade and high grade and their usage generally tends to be dependent on their location within a network (see Figure 1/G.821).



Note 1 – It is not possible to provide a definition of the location of the boundary between the medium and high grade portions of the HRX. Note 4 to Table 2/G.821 provides further clarification of this point.

Note 2 – LE denotes the local exchange or equivalent point.

FIGURE 1/G.821

Circuit quality demarcation of longest HRX

The following general assumptions apply to the apportionment strategy that follows:

- in apportioning the objectives to the constituent elements of a connection it is the "% of time" that is subdivided;
- an equal apportionment of the objectives applies for both the degraded minutes and errored seconds requirements [classifications a), c)];
- the error ratio threshold is not sub-divided. The rationale for this is based on the assumption that the performance of real circuits forming the parts of the HRX (Figure 1/G.821) will normally be significantly better than the degraded minute threshold (see Note to § 3.1);
- no account is taken of the error contribution from either digital switching elements or digital multiplex equipments on the basis that it is negligible in comparison with the contribution from transmission systems.

These quality classifications for different parts of the connection are considered to represent the situation for a large proportion of real international connections. Administrations are free to use whatever transmission systems they wish within their own networks and these other arrangements are considered as being completely acceptable provided that the overall performance of the national portion is no worse than it would have been if the standard CCITT arrangements had been employed.

It should be noted that a small percentage of connections will be longer than the 27 500 km HRX. By definition the extra connection length will be carried over high-grade circuits and hence the amount by which such connections exceed the total allowance envisaged in this Recommendation will be proportional to the amount by which the 25 000 km section is exceeded. Administrations should note that if the performance limits in the various classifications could be improved in practical implementations, the occurrence of these situations could be significantly reduced.

Note – For terrestrial systems the apportionment of the "degraded minute" performance classification to smaller entities (e.g. hypothetical reference digital section) may require sub-division of the error ratio objective, as well as the sub-division of "% of time", with distance. This is the subject of further study.

3.2 *Apportionment strategy for the* degraded minutes and *errored s*econds *requirements*

The apportionment of the permitted degradation, i.e. 10% degraded minutes and 8% errored seconds, is given in Table 2/G.821. The derived network performance objectives are given in Annex C.

TABLE 2/G.821

Allocation of the degraded minutes and errored seconds objectives for the three circuit classifications

Circuit classification	Allocation of the degraded minutes and errored seconds objectives given in Table 1/G.821
Local grade (2 ends)	15% block allowance to each end (Notes 1, 4 and 5)
Medium grade (2 ends)	15% block allowance to each end (Notes 2, 4 and 5)
High grade	40% (equivalent to conceptual quality of 0.0016% per km for 25 000 km, but see Note to § 3.1) (Notes 3, 6 and 7)

Note 1 – The local grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length.

Note 2 – The medium grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length. The actual length covered by the medium grade part of the connection will vary considerably from one country to another. Transmission systems in this classification exhibit a variation in quality falling between the other classifications.

Note 3 – The high grade apportionment is divided on the basis of length resulting in a conceptual per kilometre allocation which can be used to derive a block allowance for a defined network model (e.g. Hypothetical Reference Digital Link). For practical planning purposes of links in network models, link allowances based on the number of 280 km sections nominally 280 km (as specified in Table 2/G.921) can be used in place of the per kilometre allocation specified in this Recommendation. For longer sections which are not an exact integer multiple of 280 km, the next highest integer multiple is used.

Note 4 – The local grade and medium grade portions are permitted to cover up the first 1250 km of the circuit from the T-reference point (see Figure 1/G.821) extending into the network. For example, in large countries this portion of the circuit may only reach the Primary Centre whilst in small countries it may go as far as the Secondary Centre, Tertiary Centre or the International Switching Centre (see Figure 1/G.821).

Note 5 – Administrations may allocate the block allowances for the local and medium grade portions of the connection as necessary within the total allowance of 30% for any one end of the connection. This philosophy also applies to the objectives given for local and medium grades in Table 3/G.821.

Note 6 – Based on the understanding that satellite error performance is largely independent of distance, a block allowance of 20% of the permitted degraded minutes and errored second objectives is allocated to a single satellite HRDP employed in the high-grade portion of the HRX.

Note 7 – If the high-grade portion of a connection includes a satellite system and the remaining distance included in this category exceeds 12 500 km or if the high-grade portion of a non-satellite connection exceeds 25 000 km, then the objectives of this Recommendation may be exceeded. The occurrence of such connections is thought to be relatively rare and studies are continuing in order to investigate this. The concept of satellite equivalent distance (the length of an equivalent terrestrial path) is useful in this respect and it has been noted that a value in the range 10 000 to 13 000 km might be expected.

Note 8 – For subscriber premises installation, between the T-reference point and terminal equipment, no specific requirements are given. However careful attention should be paid to the choice of the subscriber equipment since the overall performance of the connection depends heavily, not only on the network performance, but also on the quality of the terminal installation.

3.3 *Apportionment strategy for* severely errored seconds

The total allocation of 0.2% severely errored seconds is subdivided into each circuit classification (i.e. local, medium, high grades) in the following manner:

a) 0.1% is divided between the three circuit classifications in the same proportions as adopted for the other two objectives. This results in the allocation as shown in Table 3/G.821.

TABLE 3/G.821

Allocation of severely errored seconds

Circuit classification	Allocation of severely errored seconds objectives
Local grade	0.015% block allowance to each end (Note 5 to Table 2/G.821)
Medium grade	0.015% block allowance to each end (Note 5 to Table 2/G.821)
High grade	0.04% (Notes 1, 2)

Note 1 – For transmission systems covered by the high grade classification each 2500 km portion may contribute not more than 0.004%.

Note 2 – For a satellite HRDP operating in the high grade portion there is a block allowance of 0.02% severely errored seconds (see also Note 6 to Table 2/G.821).

b) The remaining 0.1% is a block allowance to the medium and high grade classifications to accommodate the occurrence of adverse network conditions occasionally experienced (intended to mean the worst month of the year) on transmission systems. Because of the statistical nature of the occurrence of worst month effects in a world-wide connection, it is considered that the following allowances are consistent with the total 0.1% figure:

   – 0.05% to a 2500 km HRDP for radio relay systems which can be used in the high grade and the medium grade portion of the connection;

   – 0.01% to a satellite HRDP (the CCIR are continuing studies on severely errored seconds performance for satellites systems and this value may eventually need to be increased).

ANNEX A

(to Recommendation G.821)

Available and unavailable time

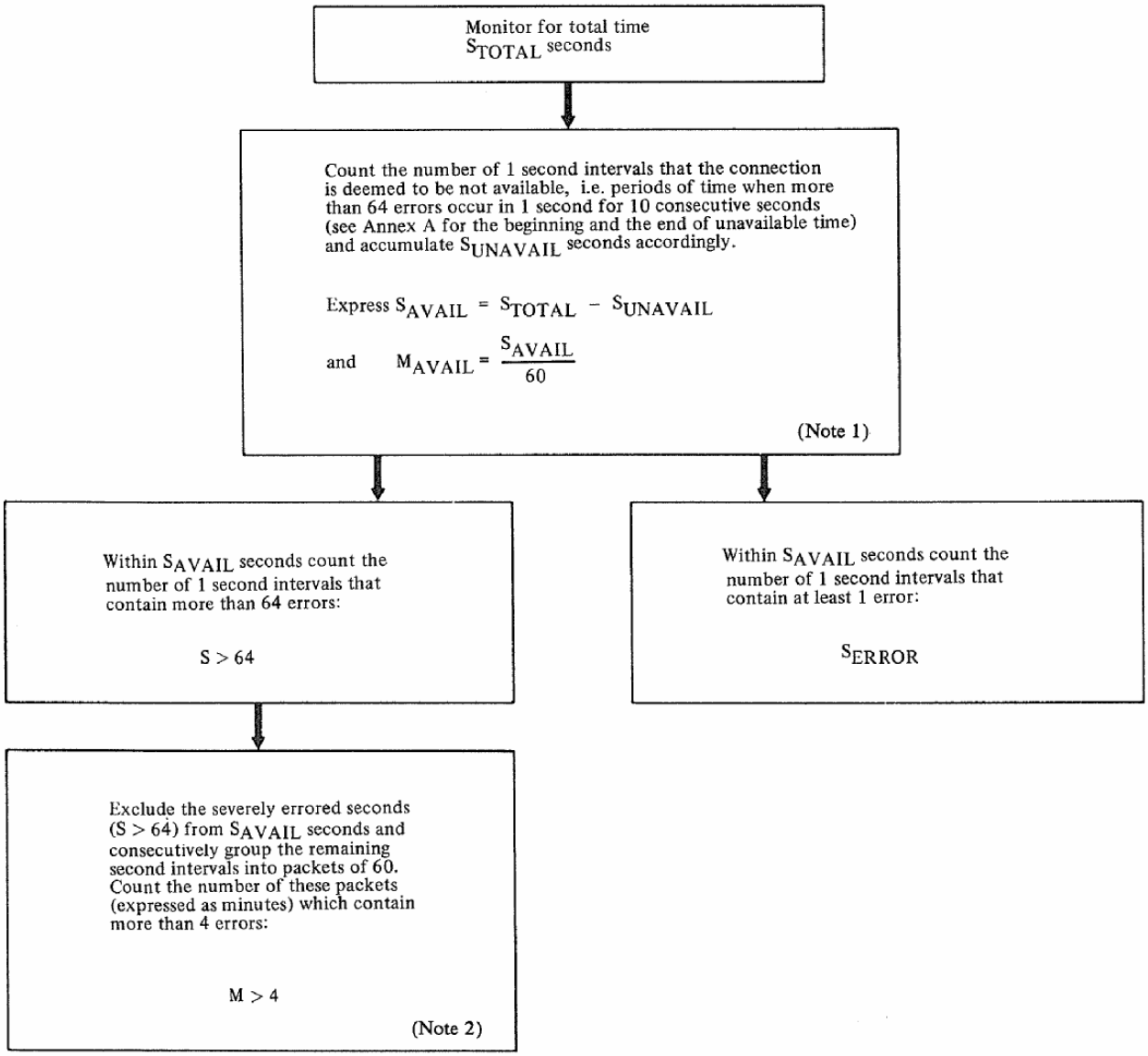
A period of unavailable time begins when the bit error ratio (BER) in each second is worse than $1 \cdot 10^{-3}$ for a period of ten consecutive seconds. These ten seconds are considered to be unavailable time. A new period of available time begins with the first second of a period of ten consecutive seconds each of which has a BER better than 10^{-3}.

Definitions concerning availability can be found in Recommendation E.800-series.

ANNEX B

(to Recommendation G.821)

Guidelines concerning the interpretation of Table 1/G.821



Note 1 – The result is rounded off to the next higher integer.

Note 2 – The last packet which may be incomplete is treated as if it were a complete packet with the same rules being applied.

Performance classification (see Table 1/G.821)	Objective
(a)	$\frac{M > 4}{M_{AVAIL}} < 10\%$
(b)	$\frac{S > 64}{S_{AVAIL}} < 0.2\%$
(c)	$\frac{S_{ERROR}}{S_{AVAIL}} < 8\%$

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ANNEX C

(to Recommendation G.821)

Allocation of objectives to constituent parts

TABLE C-1/G.821

Allocation of % degraded minute intervals and errored seconds objectives

Circuit classification (see Figure 1/G.821)	Network performance objectives at 64 kbit/s	
	% degraded minutes	% errored seconds
Local grade	1.5	1.2
Medium grade	1.5	1.2
High grade	4.0	3.2

ANNEX D

(to Recommendation G.821)

Preliminary guidelines for the assessment of the performance of higher bit rate systems

D.1 *Interim guidelines*

Recognizing the need for interim guidance, the formulas below are offered prior to the results of further study. They may be used to provide a normalized estimate (to the 64 kbit/s parameters cited in this Recommendation) of the error performance. It should be noted that the measurement may only be valid at the bit rate at which the measurement was made; this concern applies especially for certain types of bursty error distribution. Hence an assessment of system error performance by means of these formulas does not assure *compliance* with this Recommendation.

In order to estimate error performance normalized to 64 kbit/s in terms of:

– % errored seconds;

– % degraded minutes; and

– % severely errored seconds,

from error performance measurements at primary bit rates and above, the following provisional formulas are provided.

D.1.1 *Errored seconds*

The percentage errored seconds normalized to 64 kbit/s is given by:

$$\frac{1}{j}\sum_{i=1}^{i=j}\left(\frac{n}{N}\right)_i \times (100\%)$$

where:

i) n is the number of errors in the i^{th} second at the measurement bit rate;

ii) N is the higher bit rate divided by 64 kbit/s;

iii) j is the integer number of one second periods (excluding unavailable time) which comprises the total measurement period;

iv) the ratio $\left(\frac{n}{N}\right)_i$ for the i^{th} seconds is

$$\frac{n}{N}, \text{ if } 0 < n < N, \text{ or}$$

$$1, \text{ if } n \geq N$$

D.1.2 *Degraded minutes (see Note 1)*

The percentage of degraded minutes normalized to 64 kbit/s can be taken directly from measurements at primary bit rates and above, i.e. *X*% degraded minutes at the primary rate or above yields *X*% degraded minutes at 64 kbit/s.

D.1.3 *Severly errored seconds (see Note 1)*

The percentage of severly errored seconds normalized to 64 kbit/s that can be assessed from measurements made at primary bit rates and above is given by:

$$Y\% + Z\%$$

where:

Y percentage severly errored seconds at the measurement bit rate; and

Z percentage of non severely errored seconds at the measurement bit rate containing one or more loss of frame alignment at the measurement bit rate.

Note 1 – The calculation of the bit error ratio at the measurement bit rate (e.g. 10^{-6} for degraded minutes) will sometimes result in non-integral values of errors over the integration period. For clarification purposes, the next integer number of errors above the calculated value is considered to exceed the threshold of the performance objective (e.g. 123 errors over a minute for a bit rate of 2048 kbit/s, resulting in a BER worse than 10^{-6}, is considered as a degraded minute).

Note 2 – In order to assure the proper operation of:

– higher bit rate services (e.g. TV);

– 64 kbit/s services,

it is necessary to determine performance requirements for higher bit rate systems (i.e. above 64 kbit/s). While it is not clear which of these services has the most demanding requirements, in both cases it appears to be necessary to determine performance requirements for the higher bit rate systems either by using integration period much shorter than one second or by applying more stringent limits for severely errored seconds.

For 64 kbit/s services, the need for shorter integration periods or more stringent limits arises from the operation of the de-multiplexing equipment and in particular from the operation of the justification control and re-framing processes in the presence of error bursts much shorter than one second. For example, errors which do not result in severely errored seconds at the 64 kbit/s level as a result of loss of frame alignment in higher order multiplexers.

Reference

[1] CCITT Recommendation *Transmission performance objectives and recommendations*, Vol. III, Rec. G.102.

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