INTERNATIONAL TELECOMMUNICATION UNION

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THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

YELLOW BOOK

VOLUME III – FASCICLE III.3

DIGITAL NETWORKS
TRANSMISSION SYSTEMS AND MULTIPLEXING EQUIPMENT

RECOMMENDATIONS G.701-G.941

VII[TH] PLENARY ASSEMBLY
GENEVA, 10–21 NOVEMBER 1980

Geneva 1981

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CONTENTS OF THE CCITT BOOK
APPLICABLE AFTER THE SEVENTH PLENARY ASSEMBLY (1980)

YELLOW BOOK

Volume I – Minutes and reports of the Plenary Assembly.

Opinions and Resolutions.

Recommendations on:
- the organization and working procedures of the CCITT (Series A);
- means of expression (Series B);
- general telecommunication statistics (Series C).

List of Study Groups and Questions under study.

Volume II

FASCICLE II.1 – General tariff principles – Charging and accounting in international telecommunications services. Serie D Recommendations (Study Group III).

FASCICLE II.2 – International telephone service – Operation. Recommendation E.100 - E.323 (Study Group II).

FASCICLE II.3 – International telephone service – Network management – Traffic engineering. Recommendations E.401 - E.543 (Study Group II).

FASCICLE II.4 – Telegraph and "telematic services"[1)] operations and tariffs. Series F Recommendations (Study Group I).

Volume III

FASCICLE III.1 – General characteristics of international telephone connections and circuits. Recommendations G.101 - G.171 (Study Group XV, XVI, CMBD).

FASCICLE III.2 – International analogue carrier systems. Transmission media – characteristics. Recommendations G.211 - G.651 (Study Group XV, CMBD).

FASCICLE III.3 – Digital networks – transmission systems and multiplexing equipments. Recommendations G.701 - G.941 (Study Group XVIII).

FASCICLE III.4 – Line transmission of non telephone signals. Transmission of sound programme and television signals. Series H, J Recommendations (Study Group XV).

Volume IV

FASCICLE IV.1 – Maintenance; general principles, international carrier systems, international telephone circuits. Recommendations M.10 - M.761 (Study Group IV).

FASCICLE IV.2 – Maintenance; international voice frequency telegraphy and facsimile, international leased circuits. Recommendations M.800 - M.1235 (Study Group IV).

FASCICLE IV.3 – Maintenance; international sound programme and television transmission circuits. Series N Recommendations (Study Group IV).

FASCICLE IV.4 – Specifications of measuring equipment. Series O Recommendations (Study Group IV).

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1) "Telematic services" is used provisionally.

Volume V – Telephone transmission quality. Series P Recommendations (Study Group XII).

Volume VI

FASCICLE VI.1 – General Recommendations on telephone switching and signalling. Interface with the maritime service. Recommendations Q.1 - Q.118 *bis* (Study Group XI).

FASCICLE VI.2 – Specifications of signalling systems Nos. 4 and 5. Recommendations Q.120 - Q.180 (Study Group XI).

FASCICLE VI.3 – Specifications of signalling system No. 6. Recommendations Q.251 - Q.300 (Study Group XI).

FASCICLE VI.4 – Specifications of signalling systems R1 and R2. Recommendations Q.310 - Q.490 (Study Group XI).

FASCICLE VI.5 – Digital transit exchanges for national and international applications. Interworking of signalling systems. Recommendations Q.501 - Q.685 (Study Group XI).

FASCICLE VI.6 – Specifications of signalling system No. 7. Recommendations Q.701 - Q.741 (Study Group XI).

FASCICLE VI.7 – Functional Specification and Description Language (SDL). Man-machine language (MML). Recommendations Z.101 - Z.104 and Z.311 - Z.341 (Study Group XI).

FASCICLE VI.8 – CCITT high level language (CHILL). Recommendation Z.200 (Study Group XI).

Volume VII

FASCICLE VII.1 – Telegraph transmission and switching. Series R, U Recommendations (Study Group IX).

FASCICLE VII.2 – Telegraph and "telematic services"[1] terminal equipment. Series S, T Recommendations (Study Group VIII).

Volume VIII

FASCICLE VIII.1 – Data communication over the telephone network. Series V Recommendations (Study Group XVII).

FASCICLE VIII.2 – Data communication networks; services and facilities, terminal equipment and interfaces. Recommendations X.1 - X.29 (Study Group VII).

FASCICLE VIII.3 – Data communication networks; transmission, signalling and switching, network aspects, maintenance, administrative arrangements. Recommendations X.40 - X.180 (Study Group VII).

Volume IX – Protection against interference. Series K Recommendations (Study Group V). Protection of cable sheaths and poles. Series L Recommendations (Study Group VI).

Volume X

FASCICLE X.1 – Terms and definitions.

FASCICLE X.2 – Index of the Yellow Book.

[1] "Telematic services" is used provisionally.

CONTENTS OF FASCICLE III.3 OF THE YELLOW BOOK

Recommendations G.701 to G.941

Digital networks
Transmission systems and multiplexing equipments

Rec. No.		Page
SECTION 7 – *General aspects of digital transmission systems; terminal equipments*		
7.0	**General**	
G.701	Framework of the Series G.700, G.800 and G.900 Recommendations	3
G.702	Vocabulary of pulse code modulation (PCM) and digital transmission terms	6
G.703	General aspects of interfaces	34
G.704	Maintenance of digital networks	63
G.705	Integrated services digital network (ISDN)	65
7.1	**Coding of analogue signals**	
G.711	Pulse code modulation (PCM) of voice frequencies	67
G.712	Performance characteristics of PCM channels at audio frequencies	74
7.2	**General Recommendations on digital systems and paths**	
G.721	Hypothetical reference digital paths	82
G.722	Interconnection of digital paths using different techniques	84
7.3	**Principal characteristics of primary multiplex equipment**	
G.731	Primary PCM multiplex equipment for voice frequencies	85
G.732	Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s	86
G.733	Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s	93
G.734	Characteristics of 2048-kbit/s frame structure for use with digital exchanges	97
G.735	Characteristics required to terminate 1544-kbit/s digital paths on a digital exchange	100
G.736	Characteristics of synchronous digital multiplex equipment operating at 1544 kbit/s	101
G.737	Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s and offering synchronous 64-kbit/s digital access options	105
G.738	Characteristics of a synchronous digital multiplex equipment operating at 2048 kbit/s	109

Rec. No.		Page
G.739	Characteristics of an external access equipment operating at 2048 kbit/s and offering synchronous digital access at 64 kbit/s	114
7.4	**Principal characteristics of second order multiplex equipments**	
G.741	General considerations on second order multiplex equipments	119
G.742	Second order digital multiplex equipment operating at 8448 kbit/s and using positive justification	124
G.743	Second order digital multiplex equipment operating at 6312 kbit/s and using positive justification	128
G.744	Second order PCM multiplex equipment operating at 8448 kbit/s	132
G.745	Second order digital multiplex equipment operating at 8448 kbit/s and using positive/zero/negative justification	138
G.746	Characteristics of 8448 kbit/s frame structure for use with digital exchanges	142
7.5	**Principal characteristics of higher order multiplex equipments**	
G.751	Digital multiplex equipments operating at the third order bit rate of 34 368 kbit/s and the fourth order bit rate of 139 264 kbit/s and using positive justification	144
G.752	Characteristics of digital multiplex equipments based on a second order bit rate of 6312 kbit/s and using positive justification	156
G.753	Third order digital multiplex equipment operating at 34 368 kbit/s and using positive/zero/negative justification	163
G.754	Fourth order digital multiplex equipment operating at 139 264 kbit/s and using positive/zero/negative justification	167
7.9	**Other terminal equipments**	
G.791	General considerations on transmultiplexing equipments	170
G.792	Characteristics common to all transmultiplexing equipments	171
G.793	Characteristics of 60-channel transmultiplexing equipments	180
SECTION 8 – *Digital networks*		
8.1	**Organization of digital networks**	
G.811	Performance of clocks suitable for plesiochronous operation of international digital links	189
8.2	**Quality and availability targets**	
G.821	Error performance on an international digital connection forming part of an integrated services digital network	193
G.822	Controlled slip rate objectives on an international digital connection	196
SECTION 9 – *Digital line transmission systems*		
9.0	**General**	
G.901	General considerations on digital line sections and digital line systems	199

9.1 **Digital line transmission systems on cable at hierarchical bit rates**

G.911 Digital line sections and digital line systems on cable at 1544 kbit/s 201

G.912 Digital line sections and digital line systems on cable at 2048 kbit/s 203

G.913 Digital line sections and digital line systems on cable at 6312 kbit/s 206

G.914 Digital line sections and digital line systems on cable at 8448 kbit/s 207

G.915 Digital line sections and digital line systems on cable at 32 064 kbit/s 209

G.916 Digital line sections and digital line systems on cable at 34 368 kbit/s 210

G.917 Digital line sections and digital line systems on cable at 44 736 kbit/s 213

G.918 Digital line sections and digital line systems on cable at 139 264 kbit/s 214

9.2 **Digital line transmission systems on cable at nonhierarchical bit rates**

G.921 Digital line sections and digital line systems on cable at 3152 kbit/s 216

G.922 Digital line system at 564 992 kbit/s on coaxial pairs 218

9.4 **Digital line systems by FDM transmission bearers**

G.941 Digital line systems provided by FDM transmission bearers 225

REMARKS

1 The Questions entrusted to each Study Group for the Study Period 1981-1984 can be found in Contribution No. 1 to that Study Group.

2 *Units*

The following abbreviations are used, particularly in diagrams and tables, and always have the following clearly defined meanings:

dBm the absolute (power) level in decibels;

dBm0 the absolute (power) level in decibels referred to a point of zero relative level;

dBr the relative (power) level in decibels;

dBm0p the absolute psophometric power level in decibels referred to a point of zero relative level.

CCITT NOTE

In this Fascicle, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

FASCICLE III.3

Recommendations G.701 to G.941

DIGITAL NETWORKS

TRANSMISSION SYSTEMS AND MULTIPLEXING EQUIPMENTS

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SECTION 7

GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS; TERMINAL EQUIPMENTS

7.0 General

Recommendation G.701

FRAMEWORK OF THE SERIES G.700, G.800 AND G.900 RECOMMENDATIONS [1]

(Geneva, 1972; amended at Geneva, 1976 and 1980)

7.0 General

G.701 Framework of the Series G.700, G.800 and G.900 Recommendations.

G.702 Vocabulary of pulse code modulation (PCM) and digital transmission terms

G.703 General aspects of interfaces

G.704 Maintenance of digital networks

G.705 Integrated services digital network (ISDN)

7.1 Coding of analogue signals

G.711 Pulse code modulation (PCM) of voice frequencies

G.712 Performance characteristics of PCM channels at audio frequencies

G.71x PCM of other types of analogue signals (music, visual telephone, FDM blocks, television, etc.)

G.71y Other kinds of coding of analogue signals (e.g. Δ modulation)

7.2 General Recommendations on digital systems and paths

G.721 Hypothetical reference digital paths

G.722 Interconnection of digital paths using different techniques

G.72y Code conversion

G.72z Interference from the mains, etc.

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[1] Recommendations designated by a letter, followed by numbers (e.g. G.712) exist and are published. The titles of Recommendations designated by a letter, followed by numbers and another letter (e.g. G.71x) are intented to indicate the general plan for the drafting of Recommendations in the future.

7.3 Principal characteristics of primary multiplex equipment

G.731 Primary PCM multiplex equipment for voice frequencies

G.732 Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s

G.733 Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s

G.734 Characteristics of 2048 kbit/s frame structure for use with digital exchanges

G.735 Characteristics required to terminate 1544 kbit/s digital paths on a digital exchange

G.736 Characteristics of synchronous digital multiplex equipment operating at 1544 kbit/s

G.737 Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s and offering synchronous 64 kbit/s digital access options

G.738 Characteristics of a synchronous digital multiplex equipment operating at 2048 kbit/s

G.739 Characteristics of an external access equipment operating at 2048 kbit/s and offering synchronous digital access at 64 kbit/s

7.4 Principal characteristics of second order multiplex equipment

G.741 General considerations on second-order multiplex equipment

G.742 Second-order digital multiplex equipment operating at 8448 kbit/s and using positive justification

G.743 Second-order digital multiplex equipment operating at 6312 kbit/s and using positive justification.

G.744 Second-order PCM multiplex equipment operating at 8448 kbit/s

G.745 Second-order digital multiplex equipment operating at 8448 kbit/s and using positive/zero/negative justification

G.746 Characteristics of 8448 kbit/s frame structure for use with digital exchanges

G.74x Other digital and PCM second order multiplex equipment

7.5 Principal characteristics of higher order multiplex equipment

G.751 Digital multiplex equipments operating at the third order bit rate of 34 368 kbit/s and the fourth order bit rate of 139 264 kbit/s and using positive justification

G.752 Characteristics of digital multiplex equipments based on a second order bit rate of 6312 kbit/s and using positive justification.

G.753 Third order digital multiplex equipment operating at 34 368 kbit/s and using positive/zero/negative justification

G.754 Fourth order digital multiplex equipment operating at 139 264 kbit/s and using positive/zero/negative justification

7.9 Other terminal equipments

G.791 General considerations on transmultiplexing equipments

G.792 Characteristics common to all transmultiplexing equipments

G.793 Characteristics of 60-channel transmultiplexing equipments

G.79x Other kinds of transmultiplexers

SECTION 8

DIGITAL NETWORKS

8.0 General

G.80x Overall aspects of the integrated services digital network (ISDN) and of dedicated networks

8.1 Organization of digital networks

G.811 Performance of clocks suitable for plesiochronous operation of international digital links

G.81x Other Recommendations on the synchronization of digital networks

G.81y Maintenance methods and alarms

8.2 Quality and availability targets

G.821 Error performance on an international digital connection forming part of an integrated services digital network

G.822 Controlled slip rate objectives on an international digital connection

G.82x Reliability and availability

8.x Signalling and switching in ISDNs

SECTION 9

DIGITAL LINE TRANSMISSION SYSTEMS

9.0 General

G.901 General considerations on digital line sections and digital line systems

9.1 Digital line transmission systems on cable at hierarchical bit rates

G.911 Digital line sections and digital line systems on cable at 1544 kbit/s

G.912 Digital line sections and digital line systems on cable at 2048 kbit/s

G.913 Digital line sections and digital line systems on cable at 6312 kbit/s

G.914 Digital line sections and digital line systems on cable at 8448 kbit/s

G.915 Digital line sections and digital line systems on cable at 32 064 kbit/s

G.916 Digital line sections and digital line systems on cable at 34 368 kbit/s

G.917 Digital line sections and digital line systems on cable at 44 736 kbit/s

G.918 Digital line sections and digital line systems on cable at 139 264 kbit/s

9.2 Digital line transmission systems on cable at non-hierarchical bit rates

G.921 Digital line sections and digital line systems on cable at 3152 kbit/s

G.922 Digital line system at 564 992 kbit/s on coaxial pairs

9.4 Digital line systems by FDM transmission bearers

G.941 Digital line systems by FDM transmission bearers

9.5 Transmission systems on optical fibres

9.9 Digital transmission by radio

G.99x Digital transmission by radio relays

G.99y Digital transmission by satellite.

Recommendation G.702

VOCABULARY OF PULSE CODE MODULATION (PCM) AND DIGITAL TRANSMISSION TERMS

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 This Recommendation provides a vocabulary of terms and definitions that are appropriate to pulse code modulation and digital systems.

Some of the terms contained in the vocabulary already appear in the ITU *List of Definitions of Essential Telecommunication Terms* [1] and references to this List are given together with proposed new definitions where appropriate [1)].

In the interest of standardization in the drafting of documents the following abbreviations are recommended:

kbit/s,
Mbit/s,
Gbit/s.

To avoid misinterpretation of the use of the point (.) and the comma (,) in different languages to separate the whole and decimal parts, it is recommended that this should be avoided wherever possible. As an example, 2048 kbit/s is preferred to 2.048 (2,048) Mbit/s.

2 Vocabulary of pulse code modulation (PCM) and digital transmission terms

CONTENTS

2.1 General

2.2 Digital signals

2.3 Multiplexing in PCM

2.4 Frame alignment

2.5 Timing

2.6 Signalling in PCM

2.7 Audio performance

2.8 Codes

2.9 Digital networks

Alphabetical list of definitions contained in this Recommendation.

1) According to the conventions applied in this *List*, any term used, but not advised, is shown between square brackets, thus [ ].

Example: 3007 Parallel to serial converter [Dynamicizer].

Furthermore, any term which is in general use in addition to the principal term is shown between parentheses, thus ( ).

Example: 5010 Timing recovery (Timing extraction).

2.1 *General*

1001 **pulse code modulation (PCM)**

F: modulation par impulsions et codage (MIC)

S: modulación por impulsos codificados (MIC)

A process in which a signal is sampled, and the magnitude of each sample is quantized independently of other samples and converted by encoding to a digital signal.

1002 **differential pulse code modulation (DPCM)**

F: modulation différentielle par impulsions et codage (MDIC)

S: modulación por impulsos codificados diferencial (MICD)

A process in which a signal is sampled, and the difference between the actual value of each sample and its predicted value derived from the previous sample(s) is quantized and converted by encoding to a digital signal.

1003 **delta modulation**

F: modulation delta

S: modulación delta

A form of DPCM in which the magnitude of the difference between the predicted value and the actual value is encoded by one bit only, i.e. where only the sign of that difference is detected and transmitted.

1004 **sample**

F: échantillon

S: muestra

The value of a particular characteristic of a signal at a chosen instant.

1005 **sampling**

F: échantillonnage

S: muestreo

The process of taking samples, usually at equal time intervals.

1006 **sampling rate**

F: taux d'échantillonnage

S: velocidad de muestreo

The number of samples per unit time.

1007 **working range**

F: plage de fonctionnement [gamme de fonctionnement]

S: gama de funcionamiento

The permitted range of values of an analogue signal over which a transmitting or other processing equipment can operate (see Figure 1/G.702).

1008 **quantizing**

F: quantification

S: cuantificación

A process in which the magnitude of a sample is classified into one of a number of adjacent intervals. Any sample magnitude falling within a given interval is represented by a single value.

1009 **uniform quantizing**

F: quantification uniforme

S: cuantificación uniforme

Quantizing in which all the intervals are equal.

1010 **nonuniform quantizing**

F: quantification non uniforme

S: cuantificación no uniforme

Quantizing in which the intervals are not all equal.

1011 **reconstructed sample**

F: échantillon reconstitué

S: muestra reconstruida

An analogue sample generated at the output of a decoder when a specified digital signal representing a quantized value is applied to its input.

1012 **encoding; coding (in PCM)**

F: codage

S: codificación (en MIC)

The generation of character signals in accordance with a defined pulse code.

1013 **encoder; coder**

F: codeur

S: codificador

A device for encoding signal samples.

1014 **uniform encoding**

F: codage uniforme

S: codificación uniforme

The generation of character signals representing uniformly quantized samples.

1015 **nonuniform encoding**

F: codage non uniforme

S: codificación no uniforme

The generation of character signals representing nonuniformly quantized samples (see Figure 2/G.702).

1016 **decoding**

F: décodage

S: decodificación

The generation of reconstructed samples according to a pulse code.

1017 **decoder**

F: décodeur

S: decodificador

A device for decoding character signals.

1018 **codec**

F: codec

S: codec

A contraction of encoder-decoder. The term may be used when the encoder and decoder are associated in the same equipment.

Note – When used to describe an equipment the function of the equipment should qualify the title, e.g. supergroup codec, hypergroup codec.

1019 **decision value**

F: amplitude de décision

S: valor de decisión

A reference value defining the boundary between adjacent intervals in quantizing or encoding (see Figures 1/G.702 and 3/G.702).

1020 **virtual decision values**

F: amplitudes virtuelles de décision

S: valores virtuales de decisión

Two hypothetical decision values, used in quantizing or encoding, located at the ends of the working range used, and obtained by extrapolation from the real decision values (see Figure 1/G.702).

1021 **encoding law**

F: loi de codage

S: ley de codificación

The law defining the relative values of the quantum steps used in quantizing and encoding (see Figures 1/G.702 and 3/G.702).

1022 **segmented encoding law**

F: loi de codage à segments

S: ley de codificación por segmentos

An encoding law in which an approximation to a smooth law (see Figure 2*a)*/G.702) is obtained by a number of linear segments (see Figure 2*b)*/G.702).

1023 **quantizing interval**

F: intervalle de quantification

S: intervalo de cuantificación

The interval between two adjacent decision values.

2.2 *Digital Signals*

2001 **digit** [replaces 53.02 [2)]]

F: élément numérique

S: dígito

A member selected from a finite set.

Note 1 – In digital transmission, a digit may be represented by a signal element, being characterized by the dynamic nature, discrete condition and discrete timing of the element, e.g. it may be represented as a pulse of specified amplitude and duration.

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2) Such numbers refer to the *List of Definitions of Essential Telecommunication Terms* [2]. Numbers 51.01 et seq. are to be found in [3].

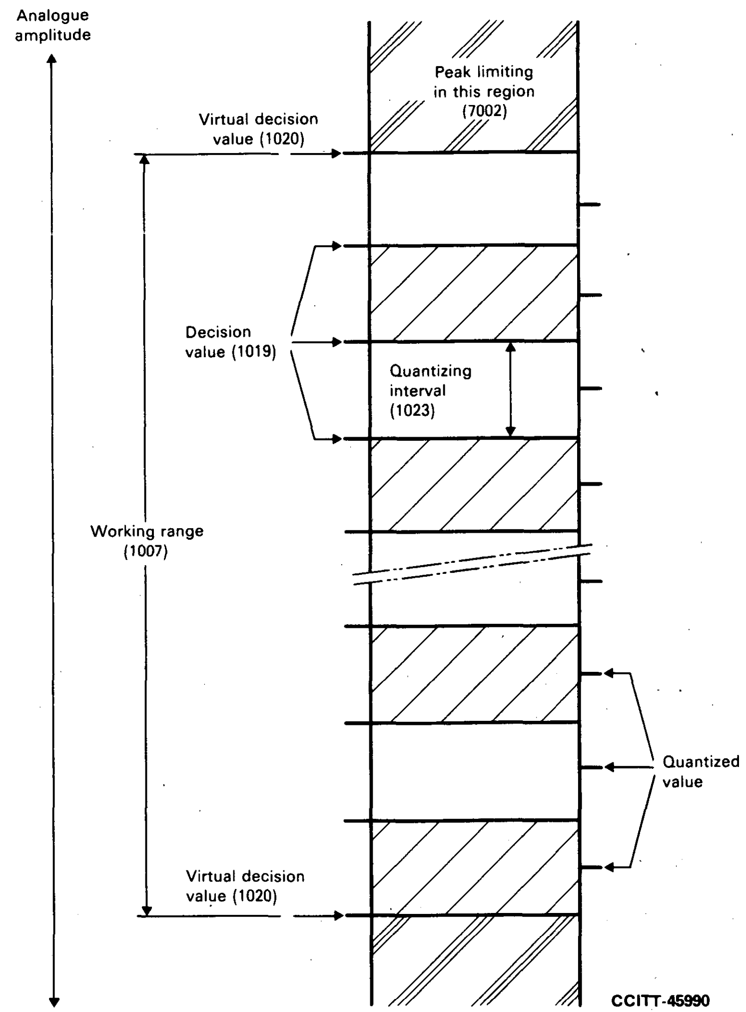
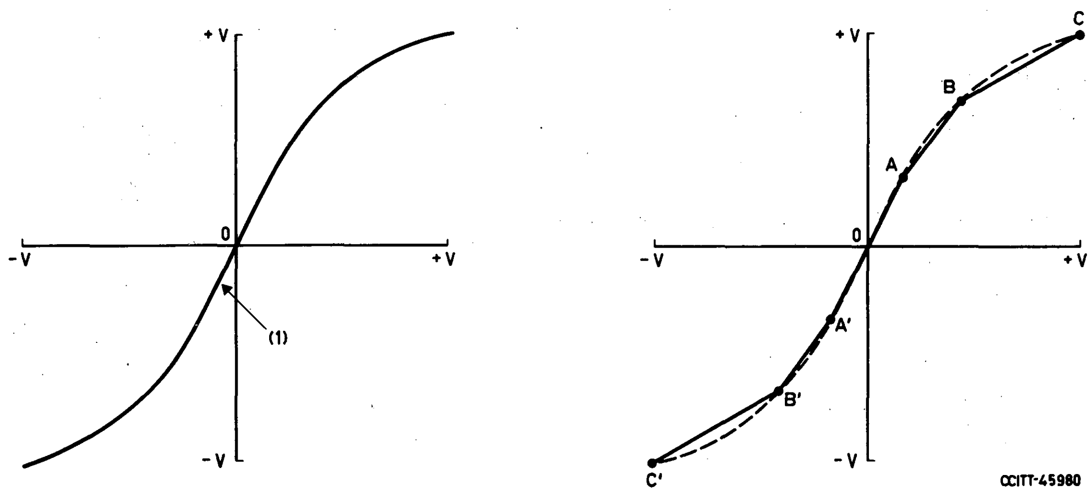


FIGURE 1/G.702

Illustration of terms associated with quantizing (1008)



a) Smooth characteristic

Note – A central linear section (1), if present, must tangentially join on to the curved end-section.

b) Segmented characteristic

Note – This particular characteristic has 5 linear segments: C′B′, B′A′, A′A, AB, BC.

FIGURE 2/G.702

Non-uniform encoding laws

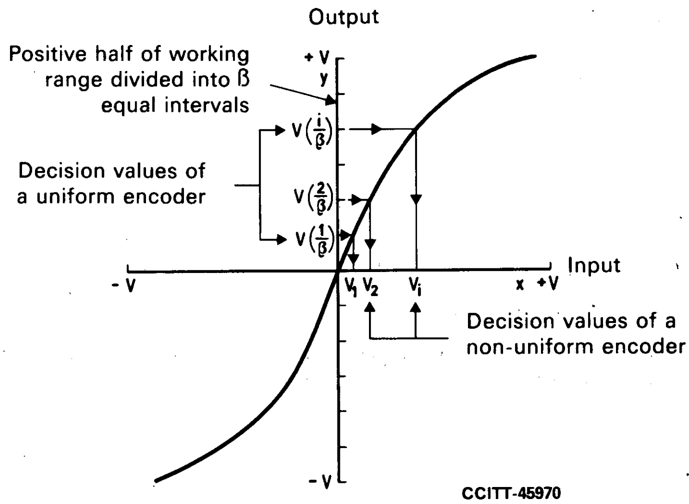


FIGURE 3/G.702

Relationship between the decision values of a uniform and a non-uniform encoding law

Note 2 – In equipment used in digital transmission, a digit may be represented by a stored condition being characterized by a specified physical condition, e.g. it may be represented as a binary magnetic condition of a ferrite core.

Note 3 – The context of the use of the term should be such as to indicate the radix of notation. (The meaning of "digit" in Notes 1, 2, and 3 translates into French as "élément numérique".)

Note 4 – In telephone subscriber numbering, a digit is any of the numbers 1, 2, 3 . . . 9 or 0 forming the elements of a telephone number (Recommendation Q.10 [4]). (This meaning of "digit" translates into French as "chiffre".)

2002 **digital signal**

F: signal numérique

S: señal digital

A signal constrained to have a discontinuous characteristic in time and a set of permitted discrete values.

2003 **digit position**

F: position d'un élément de signal; position d'un élément numérique

S: posición de digito

The position in time or space into which a representation of a digit may be placed.

2004 ***n*-ary digital signals**

F: signal numérique n-*aire*

S: señales digitales n-*arias*

Digital signals in which a signal element may assume *n* discrete states.

2005 **pseudo-ternary signal**

F: signal pseudo ternaire

S: señal seudoternaria

A redundant ternary signal which is derived from a binary signal without change of the symbol rate.

2006 **binary figure**

F: chiffre binaire

S: cifra binaria

One of the two figures (i.e. 0 or 1) used in the representation of numbers in binary notation.

2007 **binary digit** [replaces 53.01 [2)]]

F: élément binaire

S: dígito binario

A member selected from a binary set.

Note 1 – Bit is an abbreviation for binary digit.

Note 2 – In the interest of clarity, it is recommended that the term "bit" should not be used in two-condition start-stop modulation instead of "unit element".

2008 **equivalent bit rate**

F: débit binaire équivalent

S: velocidad de bits equivalente

In a line coded signal, the number of binary digits that can be transmitted in a unit of time.

Note – The point to which the equivalent bit rate is referred may be either real or hypothetical.

2009 **octet**

F: octet

S: octeto

A group of 8 binary digits operated upon as an entity.

2010 **character signal**

F: signal de caractère

S: señal de carácter

A set of signal elements representing a character, or in PCM representing the quantized value of a sample.

Note – In PCM, the term "PCM word" may be used in this sense.

2011 **significant instants of a digital signal**

F: instants significatifs d'un signal numérique

S: instantes significativos de una señal digital

The instants at which successive significant conditions of a digital signal are recognized by an appropriate device.

2012 **decision instant of a digital signal**

F: instant de décision d'un signal numérique

S: instante de decisión de una señal digital

The instant at which a decision is taken by a receiving device as to the probable value of a signal element.

2013 **digit rate**

F: débit numérique

S: velocidad digital

The number of digits per unit time.

Note 1 – An appropriate adjective should precede the word "digit", for example, binary digit rate. (This may be abbreviated to "bit rate".)

[2)] Such numbers refer to the *List of Definitions of Essential Telecommunication Terms* [2]. Numbers 51.01 et seq. are to be found in [3].

Note 2 – In the interests of clarity it is recommended that this term should not be used to express the symbol rate on the line.

2014 **digital error**

F: erreur numérique

S: error digital

A single digit inconsistency between the transmitted and received signals.

2015 **error ratio [error rate]**

F: taux d'erreur [rapport d'erreur]

S: tasa de errores [proporción de errores]

The proportion of the number of digital errors to the total number of digits. Numerical values of error ratio should be expressed as follows:

$$n \cdot 10^{-p}$$

2016 **error spread**

F: répartition des erreurs

S: dispersión de errores

The number of unit intervals over which errors in the equivalent binary content of the output signal are distributed when a single digital error is present in the input signal to an apparatus that causes error multiplication.

2017 **error multiplication**

F: multiplication d'erreurs

S: multiplicación de errores

A characteristic property of an apparatus whereby a single digital error in the signal presented to its input port results in more than one error in the digital output signal.

Note – Line code converters and descramblers are examples of apparatus that may cause error multiplication.

2018 **error multiplication factor**

F: coefficient de multiplication d'erreurs

S: factor de multiplicación de errores

The ratio of digital errors in the output signal to a single error in the input signal to an apparatus that produces error multiplication.

Note – The error multiplication factor may be expressed as either an average or maximum value.

2019 **controlled slip [slip]**

F: glissement commandé [saut]

S: deslizamiento controlado [deslizamiento]

The controlled irretrievable loss or gain of a set of consecutive digit positions in a digital signal to enable the signal to accord with a rate different from its own.

Note – Where appropriate the term may be qualified, e.g. controlled octet slip, controlled frame slip.

2020 **uncontrolled slip**

F: glissement non commandé

S: deslizamiento incontrolado

The uncontrolled loss or gain of a digit position or a set of consecutive digit positions resulting from an aberration of the timing processes associated with transmission or switching of a digital signal.

2021 **jitter**

F: gigue

S: fluctuación de fase

Short-term variations of the significant instants of a digital signal from their ideal positions in time.

2022 **regeneration**

F: régénération

S: regeneración

The process of recognizing and reconstructing a digital signal so that the amplitude, waveform and timing are constrained within stated limits.

2023 **regenerator**

F: régénérateur

S: regenerador

A device which performs signal regeneration.

2024 **regenerative repeater**

F: répéteur régénérateur

S: repetidor regenerativo

A device that performs signal regeneration together with ancillary functions.

2025 **decision circuit**

F: circuit de décision

S: circuito de decisión

A circuit that decides the probable value of a signal element.

2026 **equivalent binary content**

F: contenu binaire équivalent

S: contenido binario equivalente

The content, expressed in binary terms, of a signal generated by a digital source.

Note – The point to which the equivalent binary content is referred may be either real or hypothetical.

2027 **redundant *n*-ary signal**

F: signal n-*aire redondant*

S: señal n-*aria redundante*

A digital signal whose elements can assume *n* discrete states and where the average equivalent binary content per signal element is less than $\log_2 n$.

Note – The percent redundancy R, of an *n*-ary digital signal, is given by:

$$[1 - r_e/(r_d \cdot \log_2 n)] \cdot 100$$

where r_d is the symbol rate of the *n*-ary signal and r_e is the equivalent bit rate.

This may also be expressed in terms of the number of binary digits which can be transmitted by an element of a particular line code. Examples are:

AMI (37% redundant), 1 binary digit per element;
4B3T (16% redundant), 1.33 binary digit per element.

2028 **symbol rate**

F: débit de symboles

S: velocidad de símbolos

The reciprocal of the unit interval. This rate is expressed in bauds, if the unit internal is measured in seconds.

Note – Modulation rate is the term used in telegraphy.

2029 **scrambler**

F: embrouilleur

S: aleatorizador

In a digital system a device used to convert a digital signal into a pseudo-random digital signal without changing the bit rate.

2030 **descrambler**

F: désembrouilleur

S: desaleatorizador

A device for performing the complementary operation to that of a scrambler.

2031 **alarm indication signal**

F: signal d'indication d'alarme (SIA)

S: señal de indicación de alarma

A signal that is used to replace the normal traffic signal when a maintenance alarm indication has been activated.

2032 **upstream failure indication**

F: indication de défaillance en amont

S: indicación de fallo detrás

An indication provided by a digital multiplexer, line section or a radio section, that a signal applied at its input port is outside its prescribed maintenance limit.

2.3 *Multiplexing in PCM*

3001 **highway (American: bus)**

F: canal

S: canal principal

A common path within an apparatus or station over which signals from a plurality of channels pass separated by time division.

3002 **channel gate**

F: porte de voie

S: puerta de canal

A device for connecting a channel to a highway, or a highway to a channel, at specified times.

3003 **primary block (American: digroup)**

F: bloc primaire

S: bloque primario

A basic group of PCM channels assembled by time division multiplexing.

Note – The following conventions could be useful:

Primary block μ – a basic group of PCM channels derived from 1544-kbit/s PCM multiplex equipment.

Primary block A – a basic group of PCM channels derived from 2048-kbit/s PCM multiplex equipment.

3004 **frame**

F: trame

S: trama

A set of consecutive digit time slots in which the position of each digit time slot can be identified by reference to a frame alignment signal.

The frame alignment signal does not necessarily occur, in whole or in part, in each frame.

3005 **multiframe**

F: multitrame [groupe de trame]

S: multitrama

A set of consecutive frames in which the position of each frame can be identified by reference to a multiframe alignment signal.

The multiframe alignment signal does not necessarily occur, in whole or in part, in each multiframe.

3006 **subframe**

F: secteur de trame; sous-trame

S: subtrama

A sequence of noncontiguous sets of digits assembled within a frame, each set occurring at *n* times the frame repetition rate where *n* is an integer >1.

3007 **parallel to serial converter (American: serializer) [dynamicizer]**

F: convertisseur parallèle/série

S: convertidor paralelo/serie

A device that converts a group of digits, all of which are presented simultaneously, into a corresponding sequence of signal elements.

3008 **serial to parallel converter (American: deserializer) [staticizer]**

F: convertisseur série/parallèle

S: convertidor serie/paralelo

A device that converts a sequence of signal elements into a corresponding group of digits, all of which are presented simultaneously.

3009 **PCM multiplex equipment**

F: équipement de multiplexage MIC

S: equipo múltiplex MIC

Equipment for deriving a single digital signal at a defined digit rate from two or more analogue channels by a combination of pulse code modulation and time division multiplexing (multiplexer) and also for carrying out the inverse function (demultiplexer).

The description should be preceded by the relevant equivalent binary digit rate, e.g. 2048-kbit/s PCM multiplex equipment.

3010 **time-division multiplexing**

F: multiplexage par répartition dans le temps

S: multiplexación por división en el tiempo

Multiplexing in which two or more channels are interleaved in time for transmission over a common channel.

3011 **digital multiplexer**

F: multiplexeur numérique

S: multiplexor digital

Equipment for combining by time-division multiplexing two or more tributary digital signals into a single composite digital signal.

3012 **digital demultiplexer**

F: démultiplexeur numérique

S: demultiplexor digital

Equipment for separating a composite digital signal into its component tributary signals.

3013 **muldex**

F: muldex

S: múldex

A contraction of multiplexer – demultiplexer. The term may be used when the multiplexer and demultiplexer are associated in the same equipment.

Note – When used to describe an equipment, the function of the equipment should qualify the title e.g. PCM muldex, data muldex, digital muldex.

3014 **digital multiplex equipment**

F: équipement de multiplexage numérique

S: equipo múltiplex digital

The combination of a digital multiplexer and a digital demultiplexer at the same location.

3015 **digital multiplex hierarchy**

F: hiérarchie de multiplexage numérique

S: jerarquía de los múltiplex digitales

A series of digital multiplexers graded according to capability so that multiplexing at one level combines a defined number of digital signals, each having the digit rate prescribed for a lower order, into a digital signal having a prescribed digit rate which is then available for further combination with other digital signals of the same rate in a digital multiplexer of the next higher order.

3016 **service digits (housekeeping digits)** [replaces 53.23 [2)]]

F: éléments numériques de service

S: dígitos de servicio

Digits that are added, normally at regular time intervals to a digital signal to enable the equipment associated with that digital signal to function correctly, and possibly to provide ancillary facilities.

3017 **digital filling**

F: remplissage numérique

S: complementación digital

The addition of a fixed number of digits to a digital signal to change the digit rate from its existing nominal value to a higher predetermined nominal value.

Note – The added digits will not be used to transmit information.

3018 **justification (pulse stuffing)**

F: justification

S: justificación (relleno de impulsos)

A process of changing the rate of a digital signal in a controlled manner so that it can accord with a rate different from its own inherent rate, usually without loss of information.

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2) Such numbers refer to the *List of Definitions of Essential Telecommunication Terms* [2]. Numbers 51.01 et seq. are to be found in [3].

3019 **positive justification (positive pulse stuffing)**

F: justification positive

S: justificación positiva (relleno positivo de impulsos)

In digital multiplexing the provision of a fixed number of dedicated time slots (normally at regular intervals) in the output digital signal, these time slots being used to transmit either information from the tributaries, or no information, according to the relative digit rates of the individual tributaries and the output digital signal.

3020 **negative justification (negative pulse stuffing)**

F: justification négative

S: justificación negativa (relleno negativo de impulsos)

In digital multiplexing, the controlled deletion of digits from the tributary digital signal so that the digit rates of the individual tributaries correspond to a rate determined by the multiplex equipment. The deleted information is transmitted via a separate low-capacity time slot.

3021 **positive/zero/negative justification**

F: justification positive/nulle/négative

S: justificación positiva/nula/negativa (relleno positivo/nulo/negativo de impulsos)

A combination of positive and negative justification in which the two justification states are separately indicated by unique signals and the state of no (zero) justification is indicated by an additional signal.

3022 **justifying digit (stuffing digit)**

F: élément numérique de justification

S: dígito de justificación (dígito de relleno)

A digit inserted in a justifiable digit time slot when that time slot does not contain an information digit.

3023 **justifiable digit time slot (stuffable digit time slot)**

F: intervalle de temps pour élément numérique justifiable

S: intervalo de tiempo de dígito justificable (intervalo de tiempo de dígito rellenable)

A digit time slot that may contain either an information digit or a justifying digit.

3024 **justification service digits (stuffing service digits)**

F: éléments numériques de service de justification

S: dígitos de servicio de justificación (dígitos de servicio de relleno)

Digits that transmit information concerning the status of the justifiable digit time slots.

3025 **nominal justification rate (nominal stuffing rate)**

F: débit nominal de justification

S: velocidad nominal de justificación (velocidad nominal de relleno)

The rate at which justifying digits are inserted (or deleted) when both the tributary and the multiplex digit rates are at their nominal values.

3026 **maximum justification rate (maximum stuffing rate)**

F: débit maximal de justification

S: velocidad máxima de justificación (velocidad máxima de relleno)

The maximum rate at which justifying digits can be inserted (or deleted).

3027 **justification ratio (stuffing ratio)**

F: taux de justification

S: relación de justificación (relación de relleno)

The ratio of the actual justification rate to the maximum justification rate.

3028 **transmultiplexer**

F: transmultiplexeur

S: transmultiplexor

An equipment that transforms frequency-division multiplexed signals (such as group or supergroup) into corresponding time-division multiplexed signals that have the same structure as those derived from PCM multiplex equipment. The equipment also carries out the inverse function.

2.4 *Frame Alignment* [3]

4001 **frame alignment**

F: verrouillage de trame

S: alineación de trama

The state in which the frame of the receiving equipment is correctly phased with respect to that of the received signal.

4002 **frame alignment signal**

F: signal de verrouillage de trame

S: señal de alineación de trama

The distinctive signal used to secure frame alignment; this signal does not necessarily occur, in whole or in part, in each frame.

4003 **bunched frame alignment signal**

F: signal de verrouillage de trame concentré

S: señal de alineación de trama concentrada

A frame alignment signal in which the signal elements occupy consecutive digit time slots.

4004 **distributed frame alignment signal**

F: signal de verrouillage de trame réparti [signal de verrouillage de trame distribué]

S: señal de alineación de trama distribuida

A frame alignment signal in which the signal elements occupy nonconsecutive digit time slots.

4005 **frame alignment recovery time**

F: temps de reprise du verrouillage de trame

S: tiempo de recuperación de la alineación de trama

The time that elapses between a valid frame alignment signal being available at the receive terminal equipment and frame alignment being established.

Note – The frame alignment recovery time includes the time required for replicated verification of the validity of the frame alignment signal.

4006 **out-of-frame alignment time**

F: durée de perte du verrouillage de trame

S: duración de la pérdida de alineación de trama

The time during which frame alignment is effectively lost. That time will include the time to detect loss of frame alignment and the alignment recovery time.

---

[3] Similar definitions are applicable to multiframe alignment.

2.5 *Timing*

5001 **timing signal**

F: signal de rythme

S: señal de temporización

A cyclic signal used to control the timing of operations.

5002 **reference clock**

F: horloge de référence

S: reloj de referencia

A clock [4] of high stability and accuracy that is used to govern the frequency of clocks of lower stability. The failure of such a clock does not necessarily cause loss of synchronism.

5003 **master clock**

F: horloge maîtresse

S: reloj maestro

A clock [4] that generates accurate timing signals for the control of other clocks and possibly other equipments.

5004 **time slot**

F: intervalle de temps

S: intervalo de tiempo

Any cyclic time interval that can be recognized and defined uniquely.

5005 **channel time slot**

F: intervalle de temps de voie

S: intervalo de tiempo de canal

A time slot starting at a particular phase in a frame and allocated to a channel for transmitting a character signal and possibly in-slot signalling or other information.

Note – Where appropriate a description may be added, for example "telephone channel time slot".

5006 **signalling time slot**

F: intervalle de temps de signalisation

S: intervalo de tiempo de señalización

A time slot starting at a particular phase in each frame and allocated to the transmission of signalling.

5007 **frame alignment time slot**

F: intervalle de temps de verrouillage de trame

S: intervalo de tiempo de alineación de trama

A time slot starting at a particular phase in each frame and allocated to the transmission of a frame alignment signal.

---

4) In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

5008 **digit time slot**

F: intervalle de temps pour élément numérique

S: intervalo de tiempo de dígito

A time slot allocated to a single digit.

5009 **retiming**

F: réajustement de rythme

S: reajuste de la temporización

Adjustment of the intervals between corresponding significant instants of a digital signal, by reference to a timing signal.

5010 **timing recovery (timing extraction)**

F: récupération du rythme

S: recuperación de la temporización (extracción de la temporización)

The derivation of a timing signal from a received signal.

5011 **isochronous**

F: isochrone

S: isócrono

A signal [5] is isochronous if the time interval separating any two significant instants is theoretically equal to the unit interval or to an integral multiple of the unit interval.

Note – In practice, variations in the time intervals are constrained within specified limits.

5012 **anisochronous**

F: anisochrone

S: anisócrono

A signal [5] is anisochronous if the time interval separating any two significant instants is not necessarily related to the time interval separating any other two significant instants.

5013 **synchronous**

F: synchrone

S: síncrono

Signals [5] are synchronous if their corresponding significant instants have a desired constant phase relationship with each other.

5014 **synchronization**

F: synchronisation

S: sincronización

The process of adjusting the corresponding significant instants of signals [5] to make them synchronous.

5015 **homochronous**

F: homochrone

S: homócrono

Signals [5] are homochronous if their corresponding significant instants have a constant, but uncontrolled, phase relationship with each other.

---

[5] In these definitions "signal" is taken with the general meaning of Definition 02.27 [5].

5016 **mesochronous**

F: mésochrone

S: mesócrono

Signals [5] are mesochronous if their corresponding significant instants occur at the same average rate.

Note – The phase relationship between corresponding significant instants usually varies between specified limits.

5017 **plesiochronous**

F: plésiochrone

S: plesiócrono

Signals [5] are plesiochronous if their corresponding significant instants occur at nominally the same rate, any variation in rate being constrained within specified limits.

Note 1 – Two signals having the same nominal digit rate, but not stemming from the same clock [4] or homochronous clocks, are usually plesiochronous.

Note 2 – There is no limit to the phase relationship between corresponding significant instants.

5018 **heterochronous**

F: hétérochrone

S: heterócrono

Signals [5] are heterochronous if their corresponding significant instants do not necessarily occur at the same rate.

Note 1 – Two signals having different nominal digit rates, and not stemming from the same clock or from homochronous clocks [4] are usually heterochronous.

Note 2 – Terms 5011 to 5018 are based on the following Greek roots:

iso = equal
syn = together
homo = same
meso = middle
plesio = near
hetero = different

2.6 *Signalling in PCM*

6001 **signalling**

F: signalisation

S: señalización

The exchange of electrical information (other than by speech) specifically concerned with the establishment and control of connections, and management, in a communication network.

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4) In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

5) In these definitions "signal" is taken with the general meaning of Definition 02.27 [5].

6002 **speech digit signalling**

F: signalisation par éléments numériques vocaux

S: señalización por dígitos de conversación

A type of channel-associated signalling in which digit time slots primarily used for the transmission of encoded speech are periodically used for signalling.

6003 **in-slot signalling**

F: signalisation dans l'intervalle de temps

S: señalización dentro del intervalo

Signalling associated with a channel and transmitted in a digit time slot permanently (or periodically) allocated in the channel time slot.

6004 **out-slot signalling**

F: signalisation hors intervalle de temps

S: señalización fuera del intervalo

Signalling associated with a channel but transmitted in one or more separate digit time slots not within the channel time slot.

6005 **common channel signalling**

F: signalisation sur voie commune; signalisation par canal sémaphore

S: señalización por canal común

A signalling technique in which signalling information relating to a multiplicity of circuits, and other information such as that used for network management, is conveyed over a single channel by addressed messages.

6006 **channel associated signalling**

F: signalisation voie par voie

S: señalización asociada al canal

A signalling method in which the signals necessary for the traffic carried by a single channel are transmitted in the channel itself or in a signalling channel permanently associated with it.

2.7 *Audio performance*

7001 **load capacity (overload point)**

F: capacité de charge [point de surcharge]

S: nivel de sobrecarga (punto de sobrecarga) [capacidad de carga]

In PCM, the level expressed in dBm0, of a sinusoidal signal the positive and negative peaks of which coincide with the positive and negative virtual decision values of the encoder.

7002 **peak limiting**

F: limitation de crête

S: limitación de cresta

In PCM, the effect caused by the application to an encoder of an input signal whose value exceeds the virtual decision values of the encoder (see Figure 1/G.702).

7003 **quantizing distortion**

F: distorsion de quantification

S: distorsión de cuantificación

The distortion resulting from the process of quantizing.

7004 **quantizing distortion power**

F: puissance de distorsion de quantification

S: potencia de la distorsión de cuantificación

The power of the distortion component of the output signal resulting from the process of quantizing.

2.8 *Codes*

8001 **pulse code**

F: code de modulation d'impulsions

S: código de impulsos

A code giving the equivalence between the quantized value of a sample and the corresponding character signal.

8002 **line code**

F: code en ligne

S: código en línea

A code chosen to suit the transmission medium and giving the equivalence between a set of digits generated in a terminal or other processing equipment and the pulses chosen to represent that set of digits for line transmission.

8003 **alternate mark inversion signal (AMI) (bipolar signal)**

F: signal bipolaire (alternant); signal bipolaire (strict)

S: señal AMI (señal de inversión de marcas alternada) [señal bipolar]

A pseudo-ternary signal, conveying binary digits, in which successive "marks" are normally of alternating, positive and negative polarity but equal in amplitude, and in which "space" is of zero amplitude.

8004 **alternate mark inversion violation (bipolar violation)**

F: violation de la règle de bipolarité; violation de l'alternance des polarités

S: violación AMI [violación bipolar]

A "mark" which has the same polarity as the previous "mark" in the transmission of AMI signals.

8005 **modified alternate mark inversion**

F: signal bipolaire modifié

S: señal AMI modificada

An AMI signal that does not strictly conform with alternate mark inversion but includes violations in accordance with a defined set of rules.

Examples of such signals are HDB, B6ZS.

8006 **disparity**

F: disparité

S: disparidad

The digital sum of a set of *n* signal elements.

8007 **digital sum**

F: somme numérique

S: suma digital

In a multilevel code, the algebraic sum of positive and negative pulse amplitudes. The sum is taken from an arbitrary time origin to the last transmitted pulse at the time considered and the amplitude units are chosen with reference to the mean d.c. level in such a way that adjacent levels differ by one unit.

8008 **digital sum variation**

F: variation de la somme numérique

S: variación de la suma digital

The difference between the maximum and the minimum possible digital sum in any coded sequence of a given code.

8009 **balanced code**

F: code à somme bornée

S: código equilibrado

A code that has no d.c. component in its frequency spectrum.

8010 **paired-disparity code (alternative code) (alternating code)**

F: code à disparité compensée

S: código con disparidad compensada

A code in which some or all of the digits or characters are represented by two assemblies of digits, of opposite disparity, which are used in a sequence so as to minimize the total disparity of a longer sequence of digits.

Note – An alternate mark inversion signal is an example of a paired-disparity code.

8011 **PCM binary code**

F: code binaire MIC

S: código binario MIC

A pulse code in which the quantized values are identified by binary numbers taken in order.

Note – This term should not be used for line transmission.

8012 **symmetrical binary code**

F: code binaire symétrique

S: código binario simétrico

A pulse code derived from a binary code in which the sign of the quantized value positive or negative, is represented by one digit and in which the remaining digits constitute a binary number representing the magnitude.

Note 1 – In a particular symmetrical binary code, the order of the digits and the use made of the symbols 0 and 1 in the various digit positions must be specified.

Note 2 – This term should not be used for line transmission.

8013 **code conversion**

F: transcodage

S: conversión de código

The conversion of digital signals in one code to the corresponding signals in a different code.

2.9 *Digital networks*

9001 **digital distribution frame**

F: répartiteur numérique

S: repartidor digital

A frame at which interconnections are made between the digital outputs of equipments and the digital inputs of other equipments.

9002 **section termination**

F: extrémité de section

S: extremo de sección

Point selected to be the interface between a physical transmission medium and its associated equipment.

Note – This point will usually be the connectors at the input and output of an equipment.

9003 **elementary cable section [repeater section]**

F: section élémentaire de câble [section (élémentaire) d'amplification]

S: sección elemental de cable [sección con amplificación]

All of the transmission media between the section terminations at the output of one equipment and the section terminations at the input of the following equipment.

Note 1 – An elementary cable section will usually consist of several factory lengths of cable connected together and any media (such as flexible cables) necessary to connect it to the section terminals.

Note 2 – Examples of the transmission media are a coaxial or symmetric pair, an optical fibre and a waveguide.

9004 **elementary repeater section**

F: section élémentaire amplifiée

S: sección elemental de repetición

An *elementary cable section* together with its following repeater.

9005 **elementary regenerator section [regenerator section]**

F: section élémentaire régénérée [section de régénération]

S: sección elemental de regeneración [sección de regeneración]

An *elementary cable section* together with its following regenerative repeater.

9006 **digital section** [6)]

F: section numérique

S: sección digital

The whole of the means of transmitting and receiving between two consecutive digital distribution frames (or equivalent) a digital signal of specified rate.

Note 1 – A digital section forms either a part or the whole of a digital path.

Note 2 – Where appropriate, the bit rate should qualify the title.

Note 3 – The description always applies to the combination of "go" and "return" directions of transmission, unless stated otherwise.

9007 **digital path**

F: conduit numérique

S: trayecto digital

The whole of the means of transmitting and receiving a digital signal of specified rate between those two digital distribution frames (or equivalent) at which terminal equipments or switches will be connected. Terminal equipments are those at which signals at the specified bit rate originate or terminate.

Note 1 – A digital path comprises one or more digital sections.

Note 2 – Where appropriate, the bit rate should qualify the title.

Note 3 – The description always applies to the combination of "go" and "return" directions of transmission, unless stated otherwise.

Note 4 – Digital paths interconnected by digital switches form a digital connection.

6) Figure 4/G.702 gives examples of digital sections, digital paths, digital line sections, etc.

9008 **bit sequence independence**

F: indépendance de la séquence des bits

S: independencia de la secuencia de bits

A digital path or digital section is bit sequence independent at its specified bit rate when its design objectives permit any sequence of bits at that rate, or their equivalent, to be transmitted.

Note – Practical transmission systems that are not completely bit sequence independent may be described as quasi bit sequence independent. In such cases the limitations should be clearly stated.

9009 **digit sequence integrity**

F: intégrité de la séquence des éléments numériques

S: integridad de la secuencia de dígitos

A condition in which any selected sequence of digits is the same at each end of a digital connection.

9010 **digital switching**

F: commutation numérique

S: conmutación digital

A process in which connections are established by operations on digital signals without converting them to analogue signals.

9011 **integrated digital network**

F: réseau numérique intégré

S: red digital integrada

A network in which connections established by digital switching are used for the transmission of digital signals, for a single service, for example telephony.

9012 **integrated services digital network**

F: réseau numérique avec intégration des services

S: red digital de servicios integrados

An integrated digital network in which the same digital switches and digital paths are used to establish connections for different services, for example, telephony, data, etc.

9013 **unilateral control**

F: commande unilatérale

S: control unilateral

Control between two synchronization nodes such that the frequency of the clock [4] of only one of these nodes is influenced by timing information derived from the clock of the other node.

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[4] In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

9014 **bilateral control**

F: commande bilatérale

S: control bilateral

Control between two synchronization nodes such that the frequency of the clock [4] of each of these nodes is influenced by timing information derived from the clock of the other node.

9015 **single-ended synchronization**

F: synchronisation unilatérale

S: sincronización uniterminal

A method of synchronizing a specified synchronization node with respect to another synchronization node in which synchronization information at the specified node is derived from the phase difference between the local clock [4] and the incoming digital signal from the other node.

9016 **double-ended synchronization**

F: synchronisation bilatérale

S: sincronización biterminal

A method of synchronizing a specified synchronization node with respect to another synchronization node in which synchronization information at the specified node is derived by comparing the phase difference between the local clock [4] and the incoming digital signal from the other node, with the phase difference at the other node between its local clock and the digital signal incoming from the specified node.

9017 **analogue control**

F: mode analogique

S: control analógico

Synchronization control in which the relationship between the actual phase error between clocks [4] and the error signal device is a continuous function, at least over a limited range.

9018 **linear analogue control**

F: mode analogique linéaire

S: control analógico lineal

An analogue system in which the functional relationships are of simple proportionality.

9019 **amplitude quantized control**

F: mode à quantification d'amplitude

S: control por cuantificación de amplitud

Synchronization control in which the functional relationship between actual phase error and derived error signal includes discontinuities.

Note – In practice this implies that the working range of phase errors is divided into a finite number of subranges and that a unique signal is derived for each subrange whenever the error falls within a subrange.

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[4] In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

9020 **time quantized control**

F: mode à quantification temporelle

S: control por cuantificación temporal

Synchronization control in which the error signal is derived or utilized only at a number of discrete instants, which may or may not be equally spaced in time.

9021 **synchronized network [synchronous network]**

F: réseau synchronisé [réseau synchrone]

S: red sincronizada [red síncrona]

A network in which the corresponding significant instants of nominated signals are adjusted to make them synchronous.

Note – Ideally the signals are synchronous, but they may be mesochronous in practice. By common usage such mesochronous networks are frequently described as synchronized.

9022 **nonsynchronized network**

F: réseau non synchronisé

S: red no sincronizada

A network in which the corresponding significant instants of signals need not be synchronized or mesochronous.

9023 **mutually synchronized network**

F: réseau à synchronisation mutuelle

S: red mutuamente sincronizada

A synchronized network in which each clock [4] exerts a degree of control on all others.

9024 **democratic (mutually synchronized) network**

F: réseau démocratique (à synchronisation mutuelle)

S: red democrática (mutuamente sincronizada)

A mutually synchronized network in which all clocks [4] are of equal status and exert equal amounts of control on the others, the network operating frequency (digit rate) being the mean of the natural (uncontrolled) frequencies of the population of clocks.

9025 **hierarchic (mutually synchronized) network**

F: réseau hiérarchisé (à synchronisation mutuelle)

S: red jerárquica (mutuamente sincronizada)

A mutually synchronized network in which some clocks [4] exert more control than others, the network operating frequency being a weighted mean of the natural frequencies of the population of clocks.

---

[4] In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

9026 **despotic (synchronized) network**

F: réseau (à synchronisation) despotique

S: red despótica (sincronizada)

A synchronized network in which a unique master clock [4] exists with full power of control of all other clocks.

9027 **oligarchic (synchronized) network**

F: réseau (à synchronisation) oligarchique

S: red oligárquica (sincronizada)

A synchronized network in which control is exercised by a few selected clocks [4], the remainder being controlled by these.

9028 **digital line section**

F: section de ligne numérique

S: sección de línea digital

Two consecutive line terminal equipments, their interconnecting transmission medium and the in-station cabling between them and their adjacent digital distribution frames (or equivalents), which together provide the whole of the means of transmitting and receiving between two consecutive digital distribution frames (or equivalents) a digital signal of specified rate.

Note 1 – Line terminal equipments may include the following:

- regenerators
- code converters
- scramblers
- remote power feeding
- fault location
- supervision.

Note 2 – A digital line section is a particular case of a digital section.

9029 **digital line system**

F: système de ligne numérique

S: sistema de línea digital

A specific means of providing a digital line section.

9030 **digital block**

F: bloc numérique

S: bloque digital

The combination of a digital path and associated digital multiplex equipments.

Note – The bit rate of the digital path should form part of the title.

9031 **digital line path**

F: conduit de ligne numérique

S: trayecto de línea digital

Two or more digital line sections interconnected in tandem in such a way that the specified rate of the digital signal transmitted and received is the same over the whole length of the line path between the two terminal digital distribution frames (or equivalents).

---

[4] In these definitions "clock" is taken with the general meaning of Definition 51.10 and it is assumed that where replicated soures are used for security reasons, the assembly of these is regarded as being a single clock.

For information, Definition 51.10 is reproduced below:

51.10 **clock**

F: générateur de rythme/horloge

S: reloj

Equipment providing a time base used in a transmission system to control the timing of certain functions such as the control of the duration of signal elements, the sampling, etc.

9032 **digital radio section**

F: section hertzienne numérique

S: sección radiodigital

Two consecutive radio terminal equipments and their interconnecting transmission medium which together provide the whole of the means of transmitting and receiving, between two consecutive digital distribution frames (or equivalents), a digital signal of specified rate.

Note 1 – The description always applies to the combination of "go" and "return" directions of transmission, unless stated otherwise.

Note 2 – A digital radio section is a particular case of a digital section.

9033 **digital radio system**

F: système hertzien numérique

S: sistema radiodigital

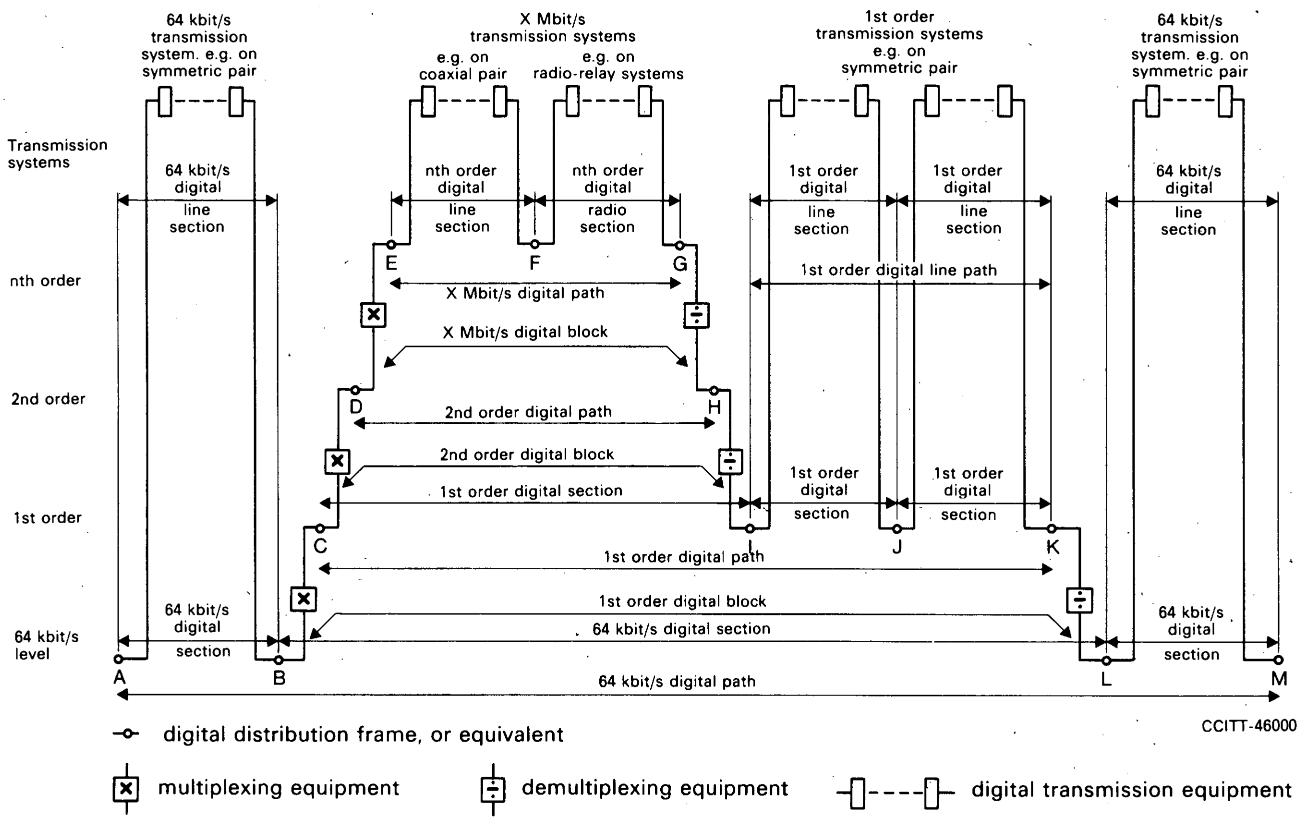
A specific means of providing a digital radio section.

9034 **digital radio path**

F: conduit hertzien numérique

S: trayecto radiodigital

Two or more digital radio sections interconnected in tandem in such a way that the specified rate of the digital signal transmitted and received is the same over the whole length of the radio path between the two terminal digital distribution frames (or equivalents).



Note 1 — Digital line and radio sections may be at digit rates which are either hierarchical or non-hierarchical.

Note 2 — A-B is a 64 kbit/s digital line section, which is a particular case of a 64 kbit/s digital section.

Note 3 — A-M is a 64 kbit/s digital path which comprises three 64 kbit/s digital sections, A-B, B-L and L-M.

Note 4 — F-G is an X Mbit/s digital radio section which forms part of an X Mbit/s digital path E-G.

Note 5 — C-I is a 1st order digital section which contains a 2nd order digital path D-H.

Note 6 — I-K is an example of a digital line path.

FIGURE 4/G.702

Examples of digital path, digital section, digital line section, etc.

Alphabetical list of definitions contained in this Recommendation

2031 Alarm indication signal
8010 (Alternative code)
8010 (Alternating code)
8005 Alternate mark inversion (modified)
8003 Alternate mark inversion signal (AMI)
8004 Alternate mark inversion violation
9019 Amplitude quantized control
9017 Analogue control
5012 Anisochronous
8009 Balanced code
9014 Bilateral control
2007 Binary digit
2006 Binary figure
8003 (Bipolar signal)
8004 (Bipolar violation)
9008 Bit sequence independence
4003 Bunched frame alignment signal
3001 (Bus: American)
6006 Channel associated signalling
3002 Channel gate
5005 Channel time slot
2010 Character signal
8013 Code conversion
1018 Codec
1013 Coder
1012 Coding
6005 Common channel signalling
2019 Controlled slip
1019 Decision value
2025 Decision circuit
2012 Decision instant of a digital signal
1017 Decoder
1016 Decoding
1003 Delta modulation
9024 Democratic (mutually synchronized) network
2030 Descrambler
3008 (Deserializer: American)
9026 Despotic (synchronized) network
1002 Differential pulse code modulation (DPCM)
2001 Digit
2003 Digit position
2013 Digit rate
9009 Digit sequence integrity
5008 Digit time slot
9030 Digital block
3012 Digital demultiplexer
9001 Digital distribution frame
2014 Digital error
3017 Digital filling
9031 Digital line path
9028 Digital line section
9029 Digital line system
3011 Digital multiplexer
3014 Digital multiplex equipment
3015 Digital multiplex hierarchy
9007 Digital path
9034 Digital radio path
9032 Digital radio section
9033 Digital radio system
9006 Digital section
2002 Digital signal
8007 Digital sum
8008 Digital sum variation
9010 Digital switching
3003 (Digroup: American)
8006 Disparity
4004 Distributed frame alignment signal
9016 Double-ended synchronization
3007 [Dynamicizer]
9003 Elementary cable section
9005 Elementary regenerator section
9004 Elementary repeater section
2017 Error multiplication
2018 Error multiplication factor
2015 [Error rate]
2015 Error ratio
2016 Error spread
1013 Encoder
1012 Encoding
1021 Encoding law
2026 Equivalent binary content
2008 Equivalent bit rate
3004 Frame
4001 Frame alignment
4002 Frame alignment signal
4005 Frame alignment recovery time
5007 Frame alignment time slot
5018 Heterochronous
9025 Hierarchic (mutually synchronized) network
3001 Highway
5015 Homochronous
3016 (Housekeeping digits)
6003 In-slot signalling
9011 Integrated digital network
9012 Integrated services digital network
5011 Isochronous
2021 Jitter
3023 Justifiable digit time slot
3018 Justification
3027 Justification ratio
3024 Justification service digits
3022 Justifying digit
8002 Line code
9028 Line section digital
9018 Linear analogue control
7001 Load capacity
5003 Master clock
3026 Maximum justification rate
3026 (Maximum stuffing rate)
5016 Mesochronous

8005 Modified alternate mark inversion
3013 Muldex
3005 Multiframe
9023 Mutually synchronized network
2004 *n*-ary digital signals
3020 Negative justification
3020 (Negative pulse stuffing)
3025 Nominal justification rate
3025 (Nominal stuffing rate)
9022 Non-synchronized network
1015 Nonuniform encoding
1010 Nonuniform quantizing
2009 Octet
9027 Oligarchic (synchronized) network
4006 Out-of-frame alignment time
6004 Out-slot signalling
7001 (Overload point)
8010 Paired-disparity code
3007 Parallel to serial converter
8011 PCM binary code
3009 PCM multiplex equipment
7002 Peak limiting
5017 Plesiochronous
3019 Positive justification
3019 (Positive pulse stuffing)
3021 Positive/zero/negative justification
3003 Primary block
2005 Pseudo ternary signal
8001 Pulse code
1001 Pulse code modulation (PCM)
3018 (Pulse stuffing)
1008 Quantizing
7003 Quantizing distortion
7004 Quantizing distortion power
1023 Quantizing interval
1011 Reconstructed sample
2027 Redundant *n*-ary signal
5002 Reference clock
2022 Regeneration
2024 Regenerative repeater
2023 Regenerator
9005 [Regenerator section]
9003 [Repeater section]
5009 Retiming
1004 Sample
1005 Sampling
1006 Sampling rate
2029 Scrambler
9002 Section termination
1022 Segmented encoding law
3008 Serial to parallel converter
3007 (Serializer: American)
3016 Service digits
6001 Signalling
5006 Signalling time slot
2011 Significant instants of a digital signal
9015 Single-ended synchronization
2019 [Slip]
6002 Speech digit signalling
3008 [Staticizer]
3023 (Stuffable digit time slot)
3018 (Stuffing)
3022 (Stuffing digit)
3027 (Stuffing ratio)
3024 (Stuffing service digits)
3006 Subframe
2028 Symbol rate
8012 Symmetrical binary code
5014 Synchronization
5013 Synchronous
9021 Synchronized network
9021 [Synchronous network]
2004 Signal (*n*-ary digital)
3010 Time-division multiplexing
9020 Time quantized control
5004 Time slot
5010 (Timing extraction)
5001 Timing signal
5010 Timing recovery
3028 Transmultiplexer
2020 Uncontrolled slip
1014 Uniform encoding
1009 Uniform quantizing
9013 Unilateral control
2032 Upstream failure indication
1020 Virtual decision value
1007 Working range

References

[1] *List of Definitions of Essential Telecommunication Terms*, 2nd edition, ITU, Geneva, 1961.

[2] *Ibid.*, Part I.

[3] *Ibid.*, 2nd Supplement, *Data Transmission.*

[4] CCITT Recommendation *Definitions relating to national and international numbering plans*, Vol. VI, Fascicle VI.1, Rec. Q.10.

[5] CCITT Definition *Signal (general sense)*, Vol. X, Fascicle X.1 (Terms and Definitions).

GENERAL ASPECTS OF INTERFACES

(Geneva, 1972; amended at Geneva, 1976 and 1980)

The CCITT,

considering

that interface specifications are necessary to enable the interconnection of digital network components (line sections, multiplex equipment, exchanges) to form an international digital path or connection,

recommends

that physical, functional and electrical characteristics of the interfaces at hierarchical bit rates should be as described in this Recommendation.

Note 1 – The characteristics of interfaces at non-hierarchical bit rates are specified in the relevant equipment Recommendations.

Note 2 – The jitter specifications contained in the following §§ 6, 7, 8 and 9 are intended to be imposed at international interconnection points.

1 Interface at 64 kbit/s

1.1 *Functional requirements*

1.1.1 The following basic requirements for the design of the interface are recommended.

1.1.2 Both in transmit and receive directions, three signals are carried across the interface:

– 64-kbit/s information signal,
– 64-kHz timing signal,
– 8-kHz timing signal.

Note 1 – An 8-kHz timing signal must be generated but it should not be mandatory for the equipment on the service side of the interface, e.g. data signals or signalling, to either utilize the 8-kHz timing signal from the PCM multiplex or time slot access equipment or supply an 8-kHz timing signal to the PCM equipment.

Note 2 – The detection of an upstream fault can be transmitted across a 64-kbit/s interface either by transmitting an Alarm Indication Signal (AIS) and/or by interruption of the 8 kHz timing signal in the receive direction.

1.1.3 The interface should be bit sequence independent at 64 kbit/s.

Note 1 – An unrestricted 64-kbit/s signal can be transmitted across the interface. However, this does not imply that unrestricted 64-kbit/s paths are realizable on a global basis. This is because some Administrations presently have or are continuing to install extensive networks composed of digital line sections whose characteristics do not permit the transmission of long sequences of 0s. (Recommendation G.733 provides for PCM multiplexes with characteristics appropriate for such digital line sections.) Specifically for octet timed sources, in 1544-kbit/s digital networks it is required that at least one binary 1 should be contained in any octet of a 64-kbit/s digital signal. For a bit stream which is not octet timed no more than 7 consecutive 0s should appear in the 64-kbit/s signal.

Note 2 – Although the interface is bit sequence independent, the use of the AIS (all 1s bit pattern) may result in some minor restrictions for the 64-kbit/s source. For example, an all 1s alignment signal could result in problems.

1.1.4 *Three types of envisaged interfaces*

1.1.4.1 *Codirectional interface*

The term codirectional is used to describe an interface across which the information and its associated timing signal are transmitted in the same direction (see Figure 1/G.703).

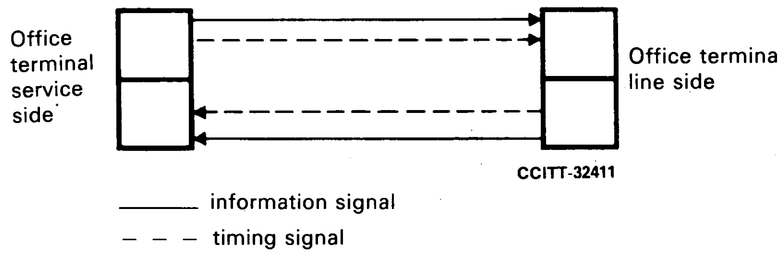


FIGURE 1/G.703

Codirectional interface

1.1.4.2 *Centralized clock interface*

The term centralized clock is used to describe an interface wherein for both directions of transmission of the information signal, the associated timing signals of both the office terminal on the line side and the office terminal on the service side are supplied from a centralized clock, which may be derived for example from certain incoming line signals (see Figure 2/G.703).

Note – The codirectional interface or centralized clock interface should be used for synchronized networks and for plesiochronous networks having clocks of the stability required (see Recommendation G.811) to ensure an adequate interval between the occurrence of slips.

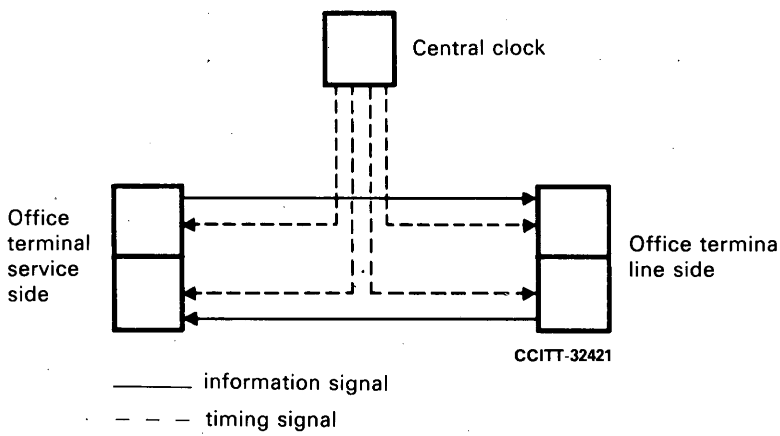


FIGURE 2/G.703

Centralized clock interface

1.1.4.3 *Contradirectional interface*

The term contradirectional is used to describe an interface across which the timing signals associated with both directions of transmission are directed towards the service side (e.g. data or signalling) of the interface. (See Figure 3/G.703.)

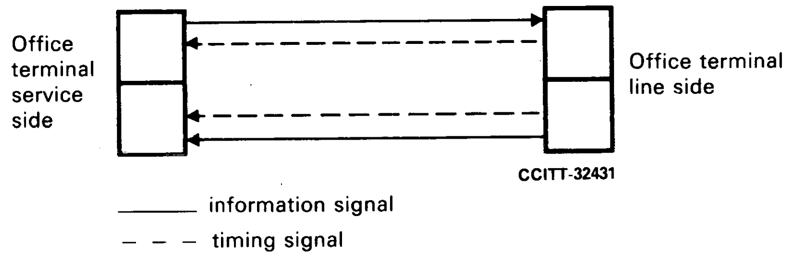


FIGURE 3/G.703
Contradirectional interface

1.2 *Electrical characteristics*

1.2.1 *Electrical characteristics of 64-kbit/s codirectional interface*

1.2.1.1 *General*

1.2.1.1.1 Nominal bit rate: 64 kbit/s.

1.2.1.1.2 Maximum tolerance of signals to be transmitted through the interface: ± 100 ppm.

1.2.1.1.3 64-kHz and 8-kHz timing signal to be transmitted in a codirectional way with the information signal.

1.2.1.1.4 One balanced pair for each direction of transmission; the use of transformers is recommended.

1.2.1.1.5 *Code conversion rules*

Step 1 – A 64-kbit/s bit period is divided into four unit intervals.

Step 2 – A binary one is coded as a block of the following four bits:

1 1 0 0

Step 3 – A binary zero is coded as a block of the following four bits:

1 0 1 0

Step 4 – The binary signal is converted into a three-level signal by alternating the polarity of consecutive blocks.

Step 5 – The alternation in polarity of the blocks is violated every 8th block. The violation block marks the last bit in an octet.

These conversion rules are illustrated in Figure 4/G.703.

1.2.1.2 *Specifications at the output ports* (see Table 1/G.703)

1.2.1.3 *Specifications at the input ports*

The digital signal presented at the input port shall be as defined above but modified by the characteristics of the interconnecting pairs. The attenuation of these pairs at a frequency of 128 kHz should be in the range 0 to 3 dB. This attenuation should take into account any losses incurred by the presence of a digital distribution frame between the equipments.

Note – If the symmetrical pair is screened, the screen shall be connected to the earth at the output port, and provision shall be made for connecting the screen of the symmetrical pair to earth, if required, at the input port.

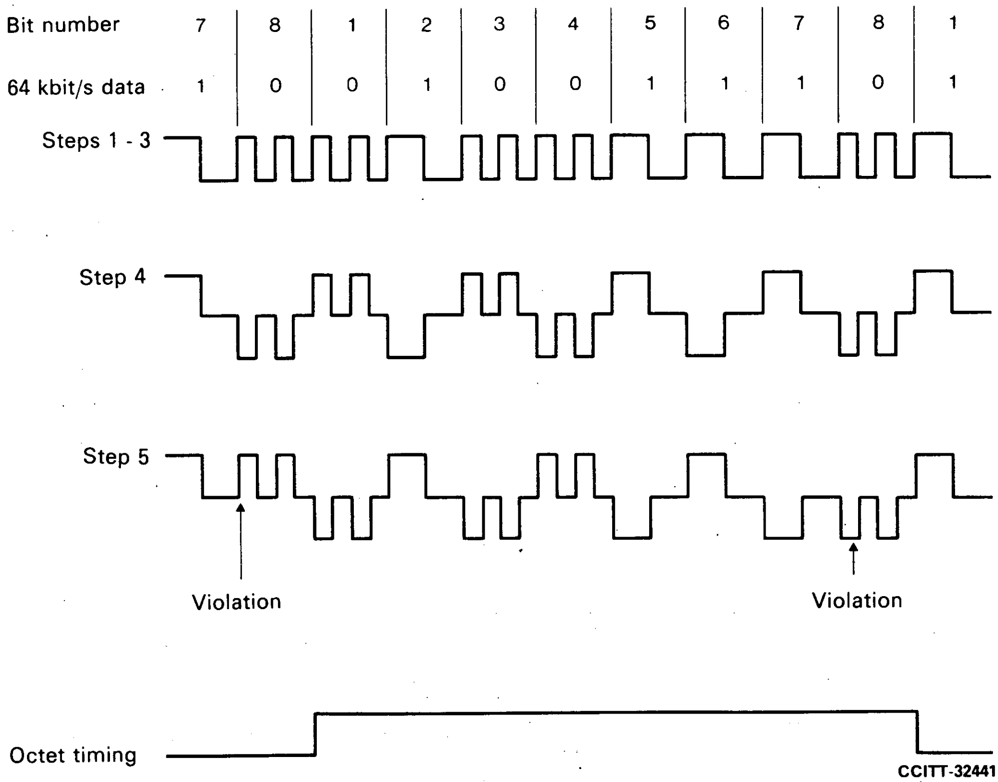
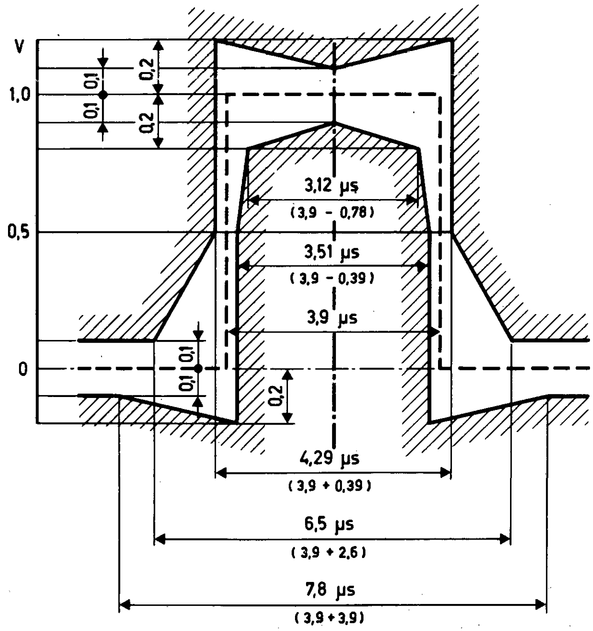


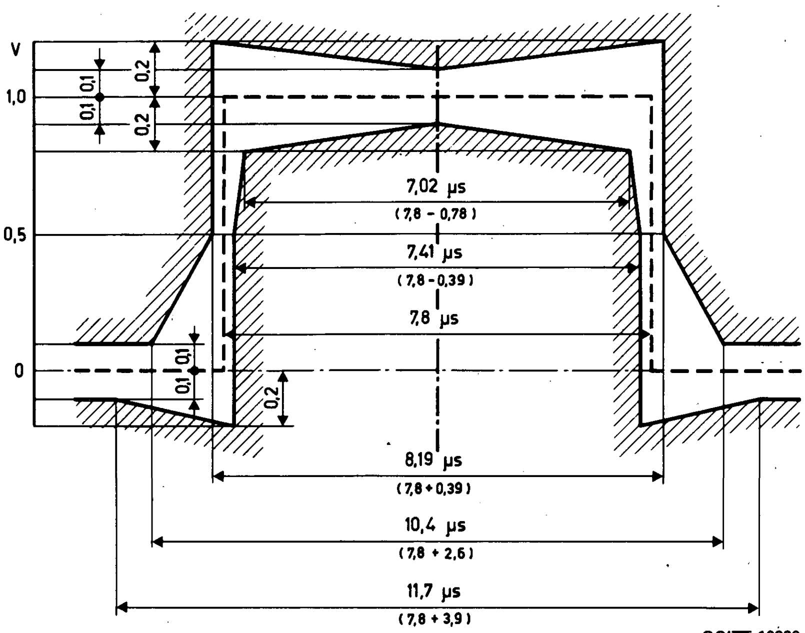
FIGURE 4/G.703

TABLE 1/G.703

Symbol rate	256 kbauds
Pulse shape (nominally rectangular)	All pulses of a valid signal must conform to the masks in Figure 5/G.703 irrespective of the polarity
Pair for each direction	One symmetric pair
Test load impedance	120 ohms resistive
Nominal peak voltage of a "mark" (pulse)	1.0 V
Peak voltage of a "space" (no pulse)	0 V ± 0.10 V
Nominal pulse width	3.9 μs
Ratio of the amplitudes of positive and negative pulses at the centre of the pulse interval	0.95 to 1.05
Ratio of the widths of positive and negative pulses at the nominal half amplitude	0.95 to 1.05



a) Mask for single pulse



b) Mask for double pulse

Note – The limits apply to pulses of either polarity.

FIGURE 5/G.703

Pulse masks of the 64 kbit/s codirectional interface

1.2.2 *Electrical characteristics of the 64-kbit/s centralized clock interface*

1.2.2.1 *General*

1.2.2.1.1 Nominal bit rate: 64 kbit/s. The tolerance is determined by the network clock stability (Reference Recommendation G.811).

1.2.2.1.2 For each direction of transmission there should be one symmetrical pair of wires carrying the data signal. In addition, there should be symmetrical pairs of wires carrying the composite timing signal (64 kHz and 8 kHz) from the central clock source to the office terminal equipment. The use of transformers is recommended.

1.2.2.1.3 *Code conversion rules*

The data signals are coded in AMI code with a 100% duty ratio. The composite timing signals convey the 64-kHz bit-timing information using AMI code with a 50% to 70% duty ratio and the 8-kHz octet-phase information by introducing violations of the code rule. The structure of the signals and their nominal phase relationships are shown in Figure 6/G.703.

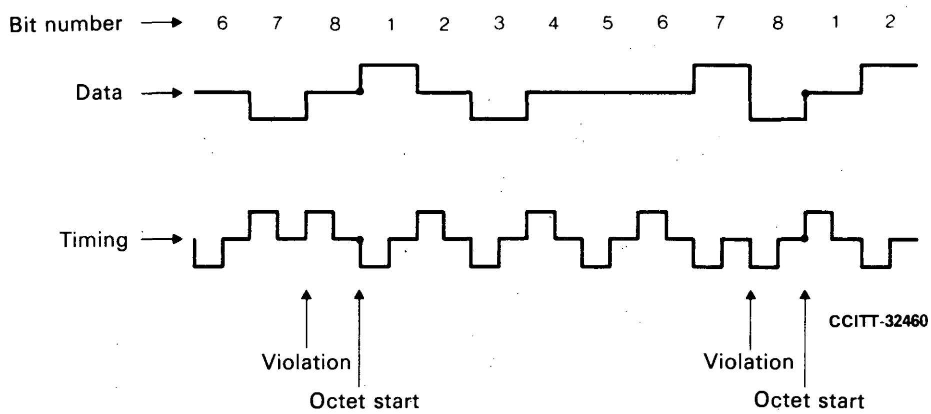


FIGURE 6/G.703

Signal structures of the 64-kbit/s central clock interface at office terminal output ports

The data stream at the output ports should be timed by the leading edge of the timing pulse and the detection instant at the input ports should be timed by the trailing edge of each timing pulse.

1.2.2.2 *Characteristics at the output ports* (see Table 2/G.703)

1.2.2.3 *Characteristics at the input ports*

The digital signals presented at the input ports should be as defined above but modified by the characteristics of the interconnecting pairs. The varying parameters in Table 2/G.703 will allow typical maximum interconnecting distances of 350 to 450 m.

1.2.2.4 *Cable characteristics*

The transmission characteristics of the cable to be used are subject to further study.

1.2.3 *Electrical characteristics of 64-kbit/s contradirectional interface*

1.2.3.1 *General*

1.2.3.1.1 Bit rate: 64 kbit/s.

1.2.3.1.2 Maximum tolerance for signals to be transmitted through the interface: ± 100 ppm.

TABLE 2/G.703

Parameters	Data	Timing
Pulse shape	Nominally rectangular, with rise and fall times less than 1 μsec.	Nominally rectangular, with rise and fall times less than 1 μsec.
Nominal test load impedance	110 ohms resistive	110 ohms resistive
Peak voltage of a "mark" (pulse)	a) 1.0 ± 0.1 V b) 3.4 ± 0.5 V	a) 1.0 ± 0.1 V b) 3.0 ± 0.5 V
Peak value of a "space" (no pulse)	a) 0 ± 0.1 V b) 0 ± 0.5 V	a) 0 ± 0.1 V b) 0 ± 0.5 V
Nominal pulse width	a) 15.6 μs b) 15.6 μs	a) 7.8 μs b) 9.8 to 10.9 μs

Note – The choice between the set of parameters a) and b) allows for different office noise environments and different maximum cable lengths between the three involved office equipments.

1.2.3.1.3 For each direction of transmission there should be two symmetrical pairs of wires, one pair carrying the data signal and the other carrying a composite timing signal (64 kHz and 8 kHz). The use of transformers is recommended.

Note – If there is a national requirement to provide a separate alarm signal across the interface, this can be done by cutting the 8-kHz timing signal for the transmission direction concerned, i.e., by inhibiting the code violations introduced in the corresponding composite timing signal (see below).

1.2.3.1.4 *Code conversion rules*

The data signals are coded in AMI code with a 100% duty ratio. The composite timing signals convey the 64-kHz bit-timing information using AMI code with a 50% duty ratio and the 8-kHz octet-phase information by introducing violations of the code rule. The structures of the signals and their phase relationships at data output ports are shown in Figure 7/G.703.

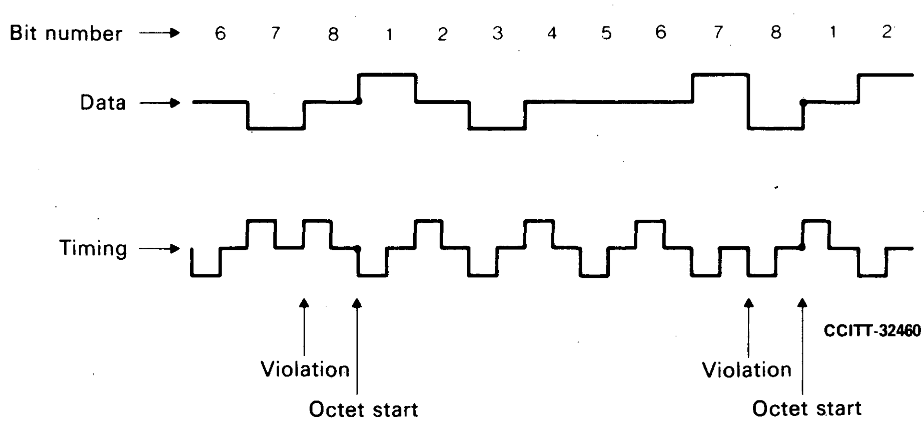


FIGURE 7/G.703

Signal structures of the 64-kbit/s contradirectional interface at data output ports

The data pulses received from the service (e.g. data or signalling) side of the interface will be somewhat delayed in relation to the corresponding timing pulses. The detection instant for a received data pulse on the line side (e.g. PCM) of the interface should therefore be at the leading edge of the next timing pulse.

1.2.3.1.5 *Specifications at the output ports* (see Table 3/G.703)

TABLE 3/G.703

Parameters	Data	Timing
Pulse shape (nominally rectangular)	All pulses of a valid signal must conform to the mask in Figure 8/G.703, irrespective of the polarity	All pulses of a valid signal must conform to the mask in Figure 9/G.703, irrespective of the polarity
Pairs in each direction of transmission	One symmetric pair	One symmetric pair
Test load impedance	120 ohms resistive	120 ohms resistive
Nominal peak voltage of a "mark" (pulse)	1.0 V	1.0 V
Peak voltage of a "space" (no pulse)	0 V ± 0.1 V	0 V ± 0.1 V
Nominal pulse width	15.6 μs	7.8 μs
Ratio of the amplitudes of positive and negative pulses at the centre of the pulse interval	0.95 to 1.05	0.95 to 1.05
Ratio of the widths of positive and negative pulses at the nominal half amplitude	0.95 to 1.05	0.95 to 1.05

1.2.3.1.6 *Specifications at the input ports*

The digital signals presented at the input ports should be as defined above but modified by the characteristics of the interconnecting pairs. The attenuation of these pairs at a frequency of 32 kHz should be in the range 0 to 3 dB. This attenuation should take into account any losses incurred by the presence of a digital distribution frame between the equipments.

Note – If the symmetrical pairs are screened, the screens shall be connected to the earth at the output port, and provision shall be made for connecting the screens of the symmetrical pairs to earth, if required, at the input port.

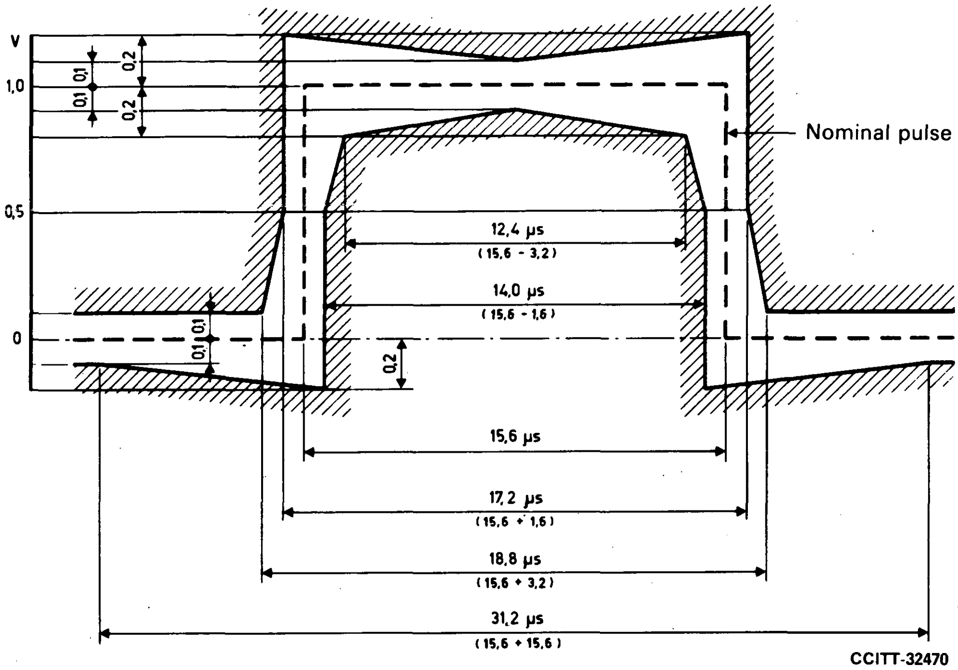
2 Interface at 1544 kbit/s

2.1 Interconnection of 1544-kbit/s signals for transmission purposes is accomplished at a digital distribution frame.

2.2 The signal shall have a bit rate of 1544 kbit/s ± 50 parts per million (ppm).

2.3 One symmetrical pair shall be used for each direction of transmission. The distribution frame jack connected to a pair bringing signals to the distribution frame is termed the in-jack.

The distribution frame jack connected to a pair carrying signals away from the distribution frame is termed the out-jack.



Note 1 – When one pulse is immediately followed by another pulse of the opposite polarity, the time limits at the zero-crossing between the pulses should be ± 0.8 μs.

Note 2 – The time instants at which a transition from one state to another in the data signal may occur are determined by the timing signal. On the service (e.g. data or signalling) side of the interface it is essential that these transitions are not initiated in advance of the timing instants given by the received timing signal.

FIGURE 8/6.703

Mask of the data pulse of the 64-kbit/s contradirectional interface

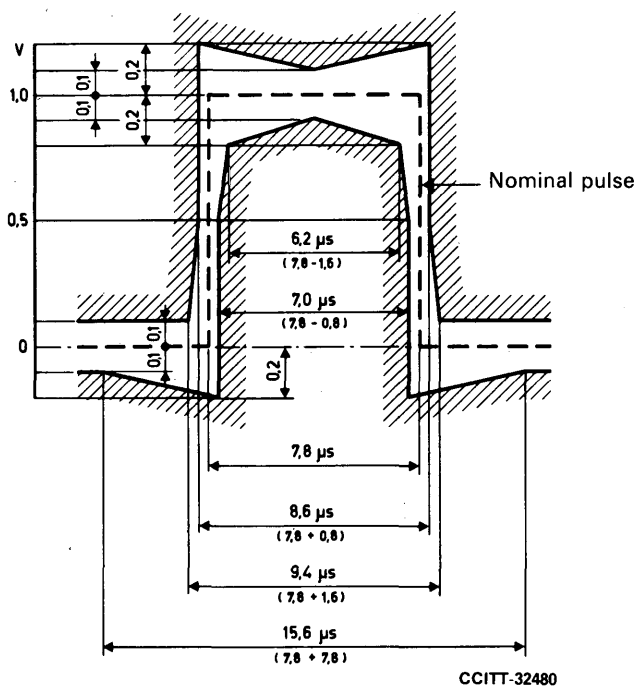


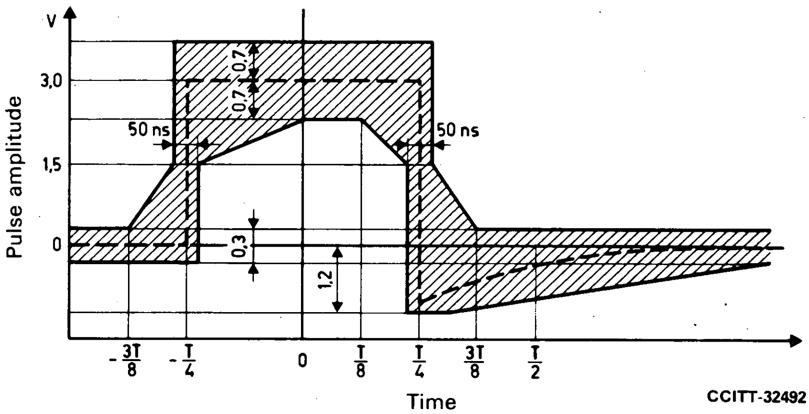
FIGURE 9/G.703

Mask of the timing pulse of the 64-kbit/s contradirectional interface

2.4 Test load impedance shall be 100 ohms, resistive.

2.5 An AMI (bipolar) code shall be used. Connecting line systems require suitable signal content to guarantee adequate timing information. This can be accomplished either by scrambling or by permitting not more than 15 spaces between successive marks and having an average mark density of at least 1 in 8.

2.6 The shape for an isolated pulse measured at either the out- or in-jack shall fall within the mask in Figure 10/G.703 and meet the other requirements of Table 4/G.703. For pulse shapes within the mask, the peak undershoot should not exceed 40% of the peak pulse (mark).



T = time-slot width

FIGURE 10/G.703

Pulse mask for interface at 1544 kbit/s

2.7 The voltage within a time slot containing a zero (space) shall be no greater than either the value produced in that time slot by other pulses (marks) within the mask of Figure 10/G.703 or ± 0.1 of the peak pulse (mark) amplitude, whichever is greater in magnitude.

TABLE 4/G.703

Digital interface at 1544 kbit/s[a)]

Location		Digital distribution frame
Bit rate		1544 kbit/s
Pair(s) in each direction of transmission		One symmetric pair
Code		AMI [b)]
Test load impedance		100 ohms resistive
Nominal pulse shape		Rectangular
Signal level [c)]	Power at 772 kHz	+ 12 dBm to + 19 dBm
	Power at 1544 kHz	At least 25 dB below the power at 772 kHz

a) The pulse mask for 1st order digital interface is shown in Figure 10/G.703.
b) See § 2.5 in the text.
c) The signal level is the power level measured in a 3-kHz bandwidth at the in-jack for an all 1s pattern transmitted.

3 Interface at 6312 kbit/s

3.1 Interconnection of 6312-kbit/s signals for transmission purposes is accomplished at a digital distribution frame.

3.2 The signal shall have a bit rate of 6312 kbit/s ± 30 ppm.

3.3 One symmetrical pair of characteristic impedance of 110 ohms, or one coaxial pair of characteristic impedance of 75 ohms shall be used for each direction of transmission. The distribution frame jack connected to a pair bringing signals to the distribution frame is termed the in-jack. The distribution frame jack connected to a pair carrying signals away from the distribution frame is termed the out-jack.

3.4 Test load impedance shall be 110 ohms resistive or 75 ohms resistive as appropriate.

3.5 A pseudo-ternary code shall be used as indicated in Table 5/G.703.

TABLE 5/G.703

Digital interface at 6312 kbit/s [a)]

Location	Digital distribution frame	
Bit rate	6312 kbit/s	
Pair(s) in each direction of transmission	One symmetric pair	One coaxial pair
Code	B6ZS [b)]	Scrambled AMI [c)]
Test load impedance	110 ohms resistive	75 ohms resistive
Nominal pulse shape	Rectangular, shaped by cable loss (see Figure 11/G.703)	Rectangular (see Figure 12/G.703)
Signal level	For an all 1s pattern transmitted, the power measured in a 3-kHz band-width should be as follows:	
	3156 kHz: 0.2 to 7.3 dBm 6312 kHz: −20 dBm or less	3156 kHz: 6.2 to 13.3 dBm 6312 kHz: −14 dBm or less

a) The pulse mask for 2nd order digital interface is shown in Figures 11/G.103 and 12/G.703.
b) Six consecutive zeros are replaced with 0+ −0− + if the preceding pulse was + ; 0− +0+ − if the preceding pulse was −.
c) An AMI code is scrambled by a five-stage reset-type scrambler with the primitive polynominal of $x^5 + x^3 + 1$.

3.6 The shape for an isolated pulse measured at either the out- or in-jack shall fall within the mask either of Figure 11/G.703 or of Figure 12/G.703 and meet the other requirements of Table 5/G.703.

3.7 The voltage within a time slot containing a zero (space) shall be no greater than either the value produced in that time slot by other pulses (marks) within the mask of Figure 11/G.703, or ± 0.1 of the peak pulse (mark) amplitude, whichever is greater in magnitude.

4 Interface at 32 064 kbit/s

4.1 Interconnection of 32 064-kbit/s signals for transmission purposes is accomplished at a digital distribution frame.

4.2 The signal shall have a bit rate of 32 064 kbit/s ± 10 ppm.

4.3 One coaxial pair shall be used for each direction of transmission. The distribution frame jack connected to a coaxial pair bringing signals to the distribution frame is termed the in-jack. The distribution frame jack connected to a coaxial pair carrying signals away from the distribution frame is termed the out-jack.

	T	Value of curve
Lower curve	$T \leqslant -0.41$ $-0.41 \leqslant T \leqslant 0.24$ $0.24 \leqslant T$	0 $0.5\left[1+\sin\frac{\pi}{2}\left(1+\frac{T}{0.205}\right)\right]$ $0.331\, e^{-1.9\,(T-0.3)}$
Upper curve	$T \leqslant -0.72$ $-0.72 \leqslant T \leqslant 0.2$ $0.2 \leqslant T$	0 $0.5\left[1+\sin\frac{\pi}{2}\left(1+\frac{T}{0.36}\right)\right]$ $0.1+0.72\, e^{-2.13\,(T-0.2)}$

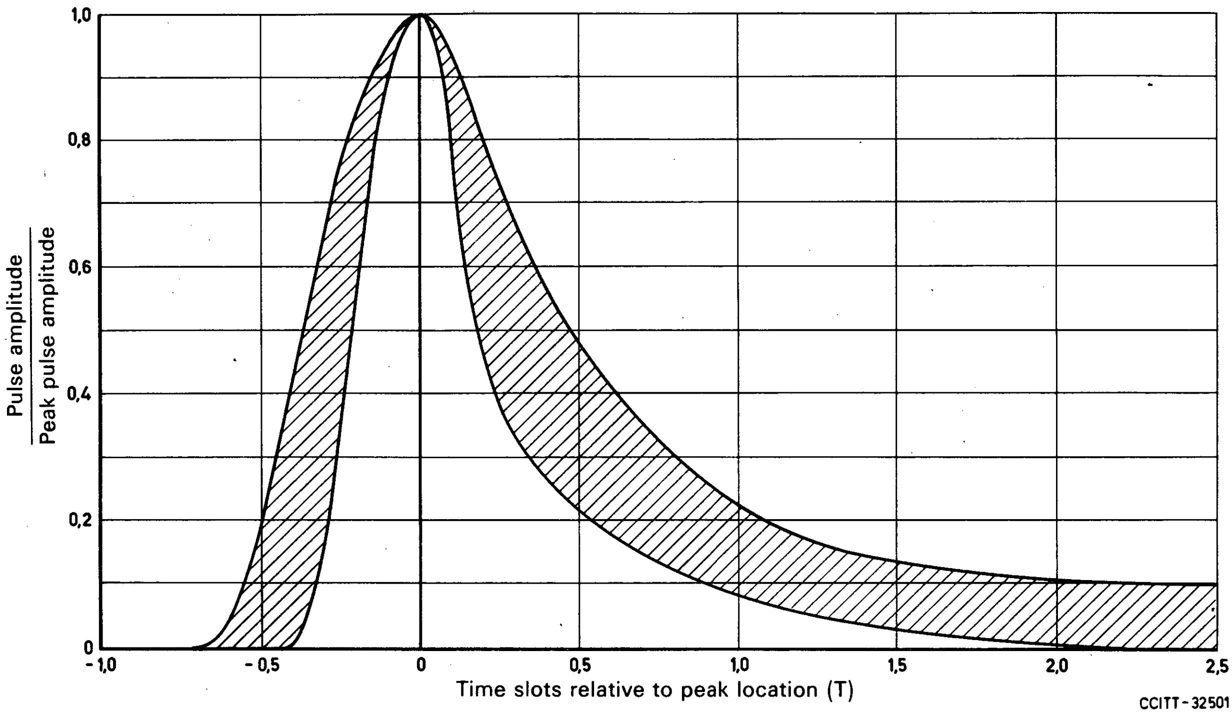
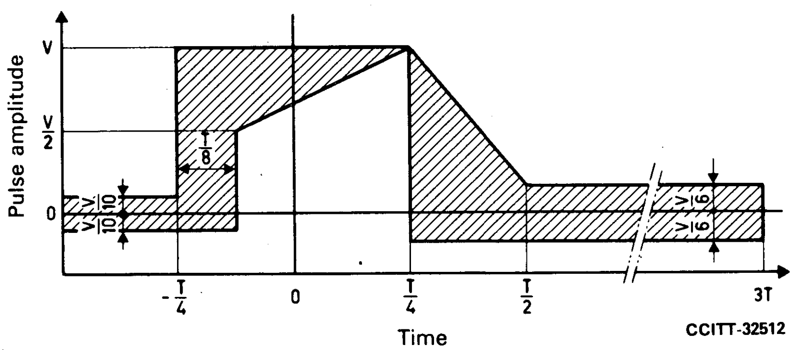


FIGURE 11/G.703

Pulse mask for the symmetric pair interface at 6312 kbit/s



T = time-slot width

FIGURE 12/G.703

Pulse mask for the coaxial pair interface at 6312 kbit/s

4.4 The test load impedance shall be 75 ohms ± 5 per cent resistive and the test method shall be direct.

4.5 A scrambled AMI code shall be used.

4.6 The shape for an isolated pulse measured at the in-jack shall fall within the mask in the Figure 13/G.703.

	T	Value of curve
Lower curve	$-0.36 \leq T < -0.30$	$5.76\,T + 2.07$
	$-0.30 \leq T < 0$	$0.5\left[1 + \sin\frac{\pi}{2}\left(1 + \frac{T}{0.25}\right)\right]$
	$0 \leq T < 0.22$	$0.5\left[1 + \sin\frac{\pi}{2}\left(1 + \frac{T}{0.16}\right)\right]$
	$0.22 \leq T$	$0.11\,e^{-3.42\,(T - 0.3)}$
Upper curve	$-0.65 \leq T < 0$	$1.05\left[1 - e^{-4.6\,(T + 0.65)}\right]$
	$0 \leq T < 0.25$	$0.5\left[1 + \sin\frac{\pi}{2}\left(1 + \frac{T}{0.28}\right)\right]$
	$0.25 \leq T$	$0.11 + 0.407\,e^{-2.1\,(T - 0.29)}$

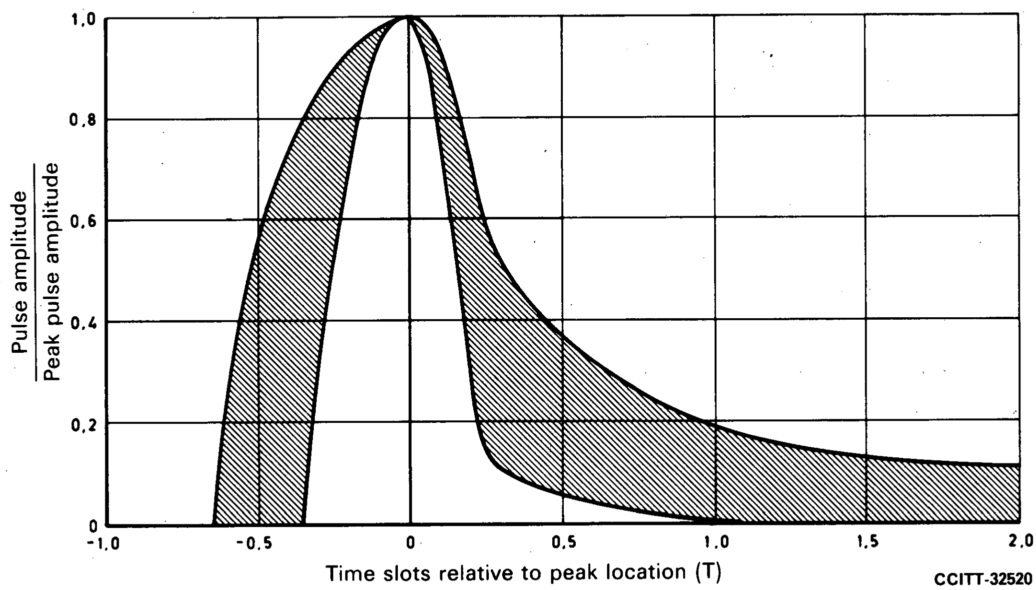


FIGURE 13/G.703

Pulse mask for the coaxial pair interface at 32 064 kbit/s

4.7 The voltage within a time slot containing a zero (space) shall be no greater than either the value produced in that time slot by other pulses (marks) within the mask of Figure 13/G.703 or ± 0.1 of the peak pulse (mark) amplitude, whichever is greater in magnitude.

4.8 For an all 1s pattern transmitted, the power measured in a 3-kHz bandwidth at the in-jack shall be as follows:

16 032 kHz: +5 dBm to +12 dBm
32 064 kHz: at least 20 dB below the power at 16 032 kHz

4.9 The connectors and coaxial cable pairs in the distribution frame shall be 75 ohms ± 5 per cent.

5 Interface at 44 736 kbit/s

5.1 Interconnection of 44 736-kbit/s signals for transmission purposes is accomplished at a digital distribution frame.

5.2 The signal shall have a bit rate of 44 736 kbit/s ± 20 ppm.

5.3 One coaxial pair shall be used for each direction of transmission. The distribution frame jack connected to a coaxial pair bringing signals to the distribution frame is termed the in-jack. The distribution frame jack connected to a coaxial pair carrying signals away from the distribution frame is termed the out-jack.

5.4 Test load impedance shall be 75 ohms ± 5 per cent resistive, and the test method shall be direct.

5.5 A bipolar code shall be used. The code shall be as specified in § 5.5.1 below.

5.5.1 *B3ZS code*

The B3ZS bipolar with three-zero substitution code is a modified bipolar pulse format. Logical 1 bits are 50 per cent duty cycle and are generally alternately positive and negative with respect to the logical 0 level. Exceptions are cases where three logical 0s appear together in the bitstream. In the B3ZS format, each block of three consecutive zeros is removed and replaced by BOV or OOV where B represents a pulse conforming with the bipolar rule and V represents a pulse violating the bipolar rule. The choice of BOV or OOV is made so that the number of B pulse between consecutive V pulses is odd. Frame alignment bits per Recommendation G.752 shall be included.

5.6 The shape for an isolated pulse measured at the in-jack shall fall within the mask in Figure 14/G.703.

5.7 The voltage within a time slot containing a zero (space) shall be no greater than either the value produced in that time slot by other pulses (marks) within the mask of Figure 14/G.703, or ± 0.05 of the peak pulse (mark) amplitude, whichever is greater in magnitude.

5.8 For an all 1s pattern transmitted, the power measured in a 3-kHz bandwidth at the in-jack shall be as follows:

22 368 kHz: −1.8 to +5.7 dBm
44 736 kHz: at least 20 dB below the power at 22 368 kHz

5.9 The digital distribution frame for 44 736 kbit/s signals shall have the characteristics specified in §§ 5.9.1 and 5.9.2 below.

5.9.1 The loss between the in- and out-jacks on the distribution frame shall be as follows:

0.60 ± 0.55 dB at 22 368 kHz
(comprised of any combination of flat and shaped losses).

5.9.2 The connectors and coaxial pair cables in the distribution frame shall be 75 ohms ± 5 per cent.

6 Interface at 2048 kbit/s

The interface described here is the preferred solution. In particular cases, such as with connections between equipment parts close to each other, an interface as described in Appendix I may be used.

	T	Value of curve
Lower curve	$T \leqslant -0.36$ $-0.36 \leqslant T \leqslant 0.28$ $0.28 \leqslant T$	0 $0.5\left[1 + \sin\frac{\pi}{2}\left(1 + \frac{T}{0.18}\right)\right]$ $0.11\, e^{-3.42\,(T\,-\,0.3)}$
Upper curve	$T \leqslant -0.65$ $-0.65 \leqslant T \leqslant 0$ $0 \leqslant T \leqslant 0.36$ $0.36 \leqslant T$	0 $1.05\,[1 - e^{-4.6\,(T\,+\,0.65)}]$ $0.5\left[1 + \sin\frac{\pi}{2}\left(1 + \frac{T}{0.34}\right)\right]$ $0.05 + 0.407\, e^{-1.84\,(T\,-\,0.36)}$

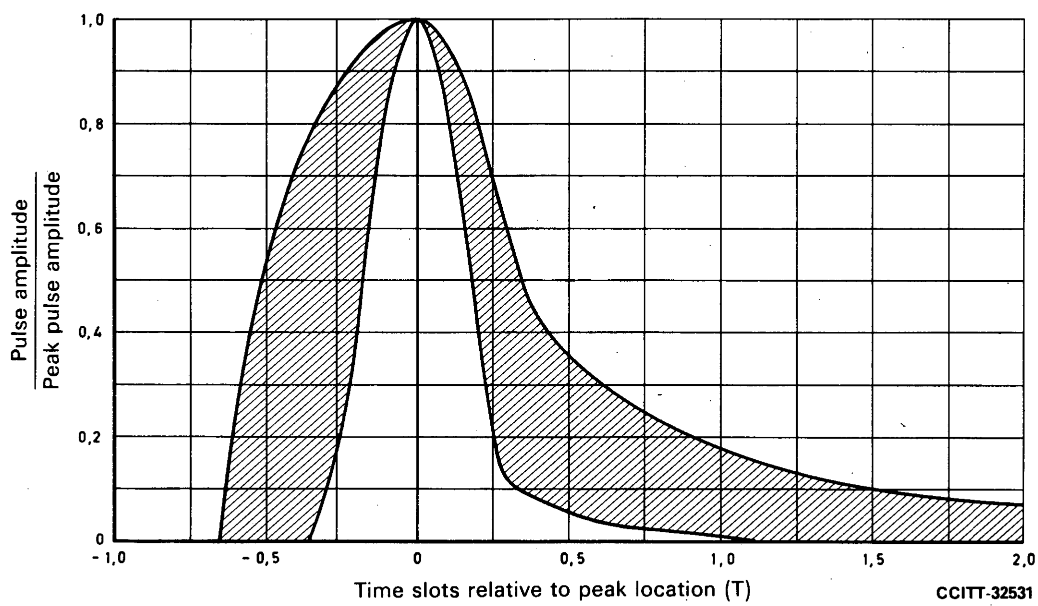


FIGURE 14/G.703

Pulse mask for the coaxial pair interface at 44 736 kbit/s

6.1 *General characteristics*

Bit rate: 2048 kbit/s ± 50 ppm
Code: HDB3 (a description of this code can be found in Annex A)

6.2 *Specifications at the output ports (see Table 6/G.703)*

The equivalent binary content of the test signal for the jitter specifications in Table 6/G.703 shall be a $2^{15} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [1]. This sequence should be encoded into the HDB3 interface code.

TABLE 6/G.703

<table>
<tr><td>Pulse shape
(nominally rectangular)</td><td colspan="3">All marks of a valid signal must conform with the mask (Figure 15/G.703) irrespective of the sign. The value V corresponds to the nominal peak value</td></tr>
<tr><td>Pair(s) in each direction</td><td>One coaxial pair
(see Note 1
to Figure 16/G.703)</td><td colspan="2">One symmetrical pair
(see Note 1
to Figure 16/G.703)</td></tr>
<tr><td>Test load impedance</td><td>75 ohms resistive</td><td colspan="2">120 ohms resistive</td></tr>
<tr><td>Nominal peak voltage of a mark (pulse)</td><td>2.37 V</td><td colspan="2">3 V</td></tr>
<tr><td>Peak voltage of a space (no pulse)</td><td>0 ± 0.237 V</td><td colspan="2">0 ± 0.3 V</td></tr>
<tr><td>Nominal pulse width</td><td colspan="3">244 ns</td></tr>
<tr><td>Ratio of the amplitudes of positive and negative pulses at the centre of the pulse interval</td><td colspan="3">0.95 to 1.05</td></tr>
<tr><td>Ratio of the widths of positive and negative pulses at the nominal half amplitude</td><td colspan="3">0.95 to 1.05</td></tr>
<tr><td rowspan="2">Maximum peak-to-peak jitter at the output port
(see Note 2)</td><td colspan="2">Measured using a high-pass filter having a cut off frequency f_1 (see Figure 16/G.703) and a roll-off of 20/dB decade</td><td>1 UI</td></tr>
<tr><td colspan="2">Measured using a high-pass filter having a cut off frequency f_3 (see Figure 16/G.703) and a roll-off 20 dB/decade</td><td>0.16 UI</td></tr>
</table>

Note 1 — Longer pseudo-random patterns may be necessary for jitter measurements on digital line systems and digital line sections (see Annex A to Recommendation G.911).

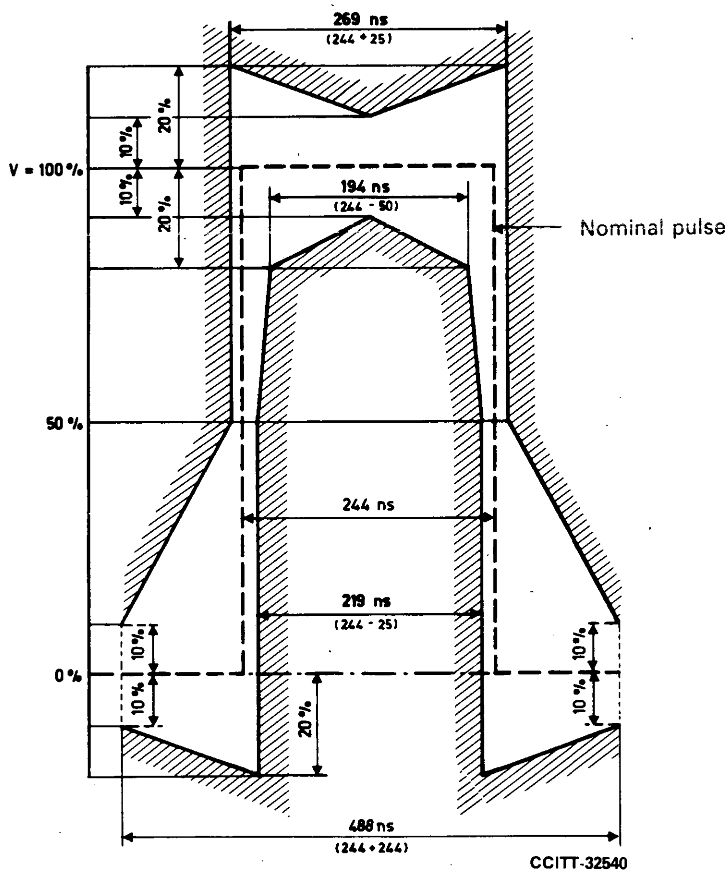
Note 2 — The jitter values are of a provisional nature. They are correlated to the lower limit of maximum tolerable input jitter as specified in § 6.3. The details of the measurement methods (time, probability, etc.) have to be further studied.

6.3 *Specifications at the input ports*

The digital signal presented at the input port shall be as defined above but modified by the characteristic of the interconnecting pair. The attenuation of this pair shall be assumed to follow a $\sqrt{f}$ law and the loss at a frequency of 1024 kHz shall be in the range 0 to 6 dB. This attenuation should take into account any losses incurred by the presence of a digital distribution frame between the equipments.

The input port shall be able to tolerate a digital signal with these electrical characteristics but modulated by sinusoidal jitter having an amplitude/frequency relationship defined in Figure 16/G.703. The equivalent binary content of the signal with jitter modulation shall be a $2^{15} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [1].

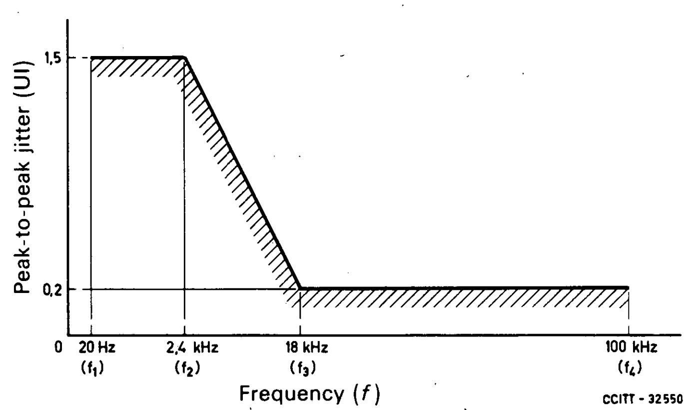
Note – Longer pseudo-random patterns may be necessary for jitter measurements on digital line systems and digital line sections (see Annex A to Recommendation G.911.



Note – V corresponds to the nominal peak value.

FIGURE 15/G.703

Mask of the pulse at the 2048 kbit/s interface



Note 1 – The outer conductor of the coaxial pair or the screen of the symmetrical pair shall be connected to the earth at the output port and provision shall be made for connecting the outer conductor of the coaxial pair or the screen of the symmetrical pair to earth if required, at the input port.

Note 2 – For interfaces within national networks only, values of $f_2 = 93$ Hz and $f_3 = 700$ Hz may be used in the mask.

FIGURE 16/G.703

Lower limit of maximum tolerable input jitter at 2048 kbit/s

7 Interface at 8448 kbit/s

The interface described here is the preferred solution. In particular cases, such as with connections between equipment parts close to each other, an interface as described in Appendix II to § 7 may be used.

7.1 *General characteristics*

Bit rate: 8448 kbit/s ± 30 ppm
Code: HDB3 (a description of this code can be found in Annex A).

7.2 *Specification at the output ports (see Table 7/G.703)*

The equivalent binary content of the test signal for the jitter specifications in Table 7/G.703 shall be a $2^{15} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [1]. This sequence should be encoded in the HDB3 interface code.

TABLE 7/G.703

Pulse shape (nominally rectangular)	All marks of a valid signal must conform with the mask (Figure 17/G.703) irrespective of the sign	
Pair(s) in each direction	One coaxial pair (see Note 1 of Figure 18/G.703)	
Test load impedance	75 ohms resistive	
Nominal peak voltage of a mark (pulse)	2.37 V	
Peak voltage of a space (no pulse)	0 ± 0.237 V	
Nominal pulse width	59 ns	
Ratio of the amplitudes of positive and negative pulses at the centre of the pulse interval	0.95 to 1.05	
Ratio of widths of positive and negative pulses at the nominal half amplitude	0.95 to 1.05	
Maximum peak-to-peak jitter at the output port (see Note 2)	Measured using a high-pass filter having a cut off frequency f_1 (see Figure 18/G.703) and a roll-off of 20 dB/decade	1 UI
	Measured using a high-pass filter having a cut off frequency f_3 (see Figure 18/G.703) and a roll-off of 20 dB/decade	0.16 UI

Note 1 — Longer pseudo-random patterns may be necessary for jitter measurements on digital line systems and digital line sections (see Annex A to Recommendation G.911).

Note 2 — The jitter values are of a provisional nature. They are correlated to the lower limit of maximum tolerable input jitter as specified in § 7.3. The details of the measurement methods (time, probability, etc.) have to be further studied.

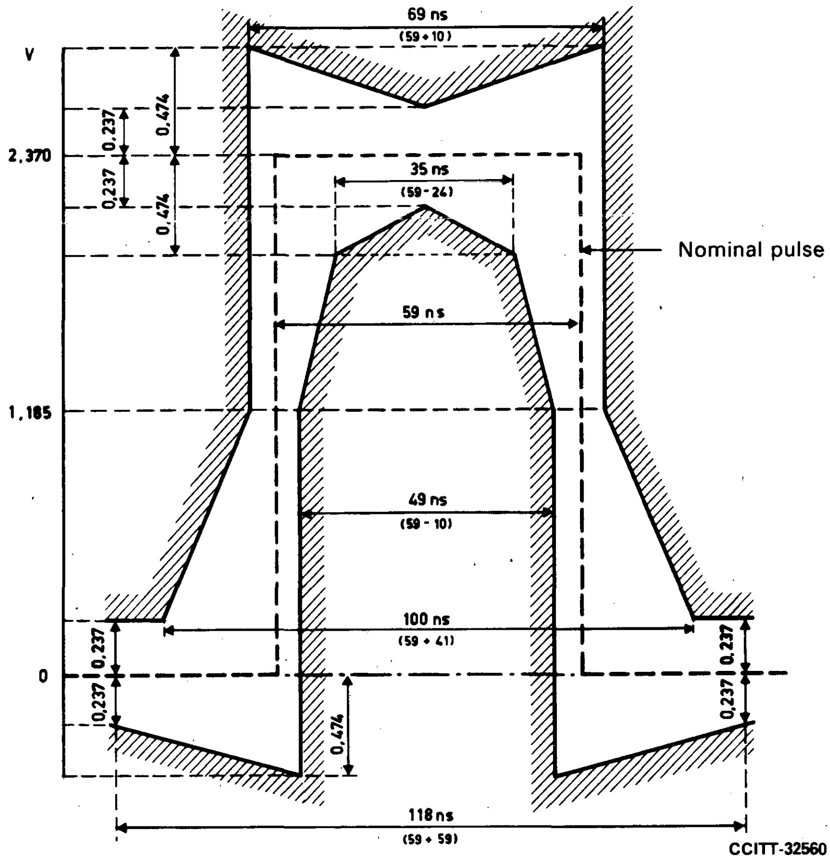
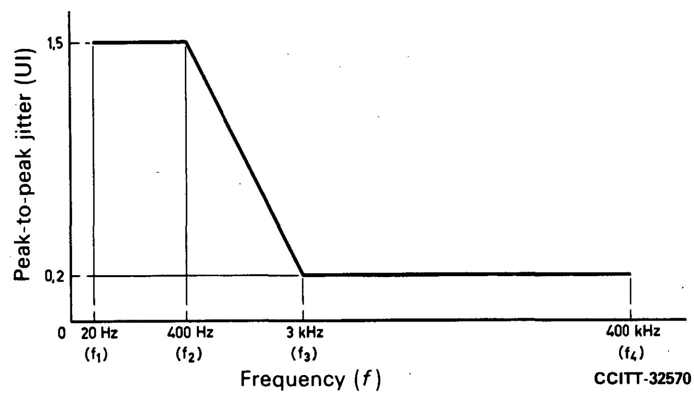


FIGURE 17/G.703

Pulse mask at the 8448-kbit/s interface



Note 1 – The outer conductor of the coaxial pair shall be connected to the earth at the output port, and provision shall be made for connecting this conductor to earth, if required, at the input port.

Note 2 – For interfaces within national networks only, values of f_2 = 10.7 kHz and f_3 = 80 kHz may be used in the mask.

FIGURE 18/G.703

Lower limit of maximum tolerable input jitter at 8448 kbit/s

7.3 *Specifications at the input ports*

The digital signal presented at the input port shall be as defined above, but modified by the characteristics of the interconnecting pairs. The attenuation of this pair shall be assumed to follow a $\sqrt{f}$ law and the loss at a frequency of 4224 kHz shall be in the range 0 to 6 dB. This attenuation should take into account any losses incurred by the presence of a digital distribution frame between the equipments.

The input port shall be able to tolerate a digital signal with these electrical characteristics but modulated by sinusoidal jitter having an amplitude/frequency relationship defined by Figure 18/G.703. The equivalent binary content of the signal with jitter modulation shall be a $2^{15} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [1].

Note – Longer pseudo-random patterns may be necessary for jitter measurements on digital line systems and digital line sections (see Annex A to Recommendation G.911).

8 Interface at 34 368 kbit/s

8.1 *General characteristics*

Bit rate: 34 368 kbit/s ± 20 ppm
Code: HDB3 (a description of this code can be found in Annex A)

8.2 *Specification at the output ports (see Table 8/G.703)*

The equivalent binary content of the test signal for the jitter specifications in Table 8/G.703 shall be a $2^{23} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [2]. This sequence should be encoded into the HDB3 interface code.

TABLE 8/G.703

Pulse shape (nominally rectangular)	All marks of a valid signal must confirm with the mask (Figure 19/G.703) irrespective of the sign	
Pair(s) in each direction	One coaxial pair (see Note to § 8.3)	
Test load impedance	75 ohms resistive	
Nominal peak voltage of a mark (pulse)	1.0 V	
Peak voltage of a space (no pulse)	0 ± 0.1 V	
Nominal pulse width	14.55 ns	
Ratio of the amplitudes of positive and negative pulses at the centre of a pulse interval	0.95 to 1.05	
Ratio of the widths of positive and negative pulses at the nominal half amplitude	0.95 to 1.05	
Maximum peak-to-peak jitter at the output port (see Note)	Measured using a high-pass filter having a cut off frequency f_1 (see Figure 20/G.703) and a roll-off of 20 dB/decade	1.2 UI
	Measured using a high-pass filter having a cut off frequency f_3 (see Figure 20/G.703) and a roll-off of 20 dB/decade	0.12 UI

Note — The jitter values are of a provisional nature. They are correlated to the lower limit of maximum tolerable input jitter as specified in § 8.3. The details of the measurement methods (time, probability, etc.) have to be further studied.

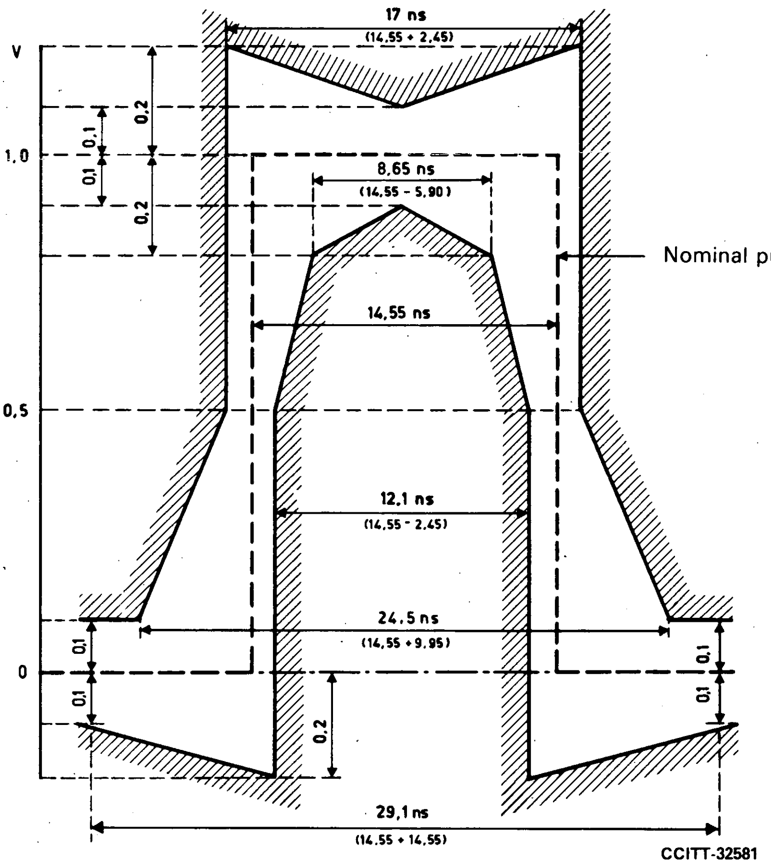
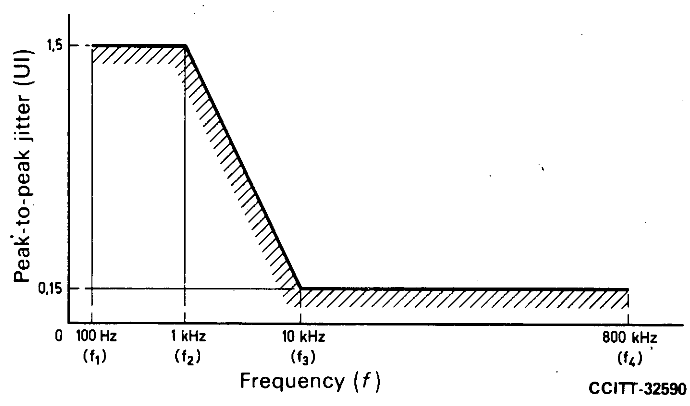


FIGURE 19/G.703

Pulse mask at the 34 368-kbit/s interface



Note – The outer conductor of the coaxial pair shall be connected to the earth at the input port and provision shall be made for connecting this conductor to earth, if required, at the input port.

FIGURE 20/G.703

Lower limit of maximum tolerable input jitter at 34 368 kbit/s

8.3 *Specifications at the input ports*

The digital signal presented at the input port shall be as defined above but modified by the characteristics of the interconnecting cable. The attenuation of this cable shall be assumed to follow approximately a $\sqrt{f}$ law and the loss at a frequency of 17 184 kHz shall be in the range 0 to 12 dB.

The input port shall be able to tolerate a digital signal with these electrical characteristics but modulated by sinusoidal jitter having an amplitude/frequency relationship defined by Figure 20/G.703. The equivalent binary content of the signal with jitter modulation shall be a $2^{23} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [2].

9 Interface at 139 264 kbit/s

9.1 *General characteristics*

Bit rate: 139 264 kbit/s ± 15 ppm
Code: **coded mark inversion (CMI)**

CMI is a 2-level non-return-to-zero code in which binary 0 is coded so that both amplitude levels, A_1 and A_2, are attained consecutively, each for half a unit time interval (T/2).

Binary 1 is coded by either of the amplitude levels A_1 or A_2, for one full unit time interval (T), in such a way that the level alternates for successive binary 1s.

An example is given in Figure 21/G.703.

Note 1 – For binary 0, there is always a positive transition at the midpoint of the binary unit time interval.

Note 2 – For binary 1,

a) there is a positive transition at the start of the binary unit time interval if the proceeding level was A_1;

b) there is a negative transition at the start of the binary unit time interval if the last binary 1 was encoded by level A_2.

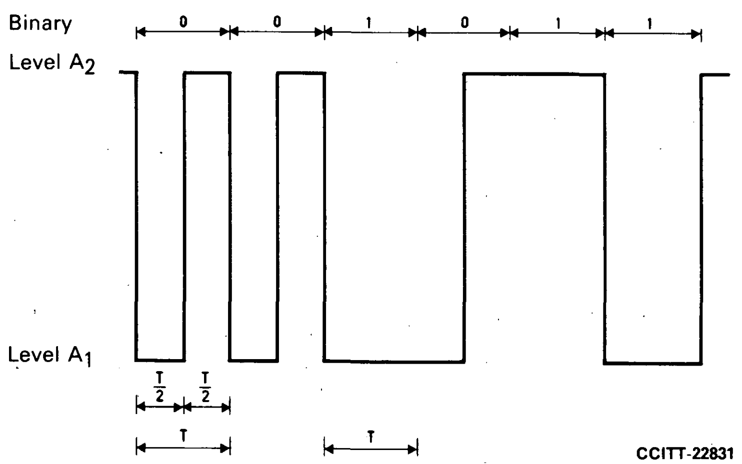


FIGURE 21/G.703
Example of CMI coded binary signal

9.2 *Specifications at the output ports (see Table 9/G.703)*

The equivalent binary content of the test signal for the jitter specifications in Table 9/G.703 shall be a $2^{23} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [2]. This sequence should be encoded into the CMI interface code.

Note 1 – A method based on the measurement of the levels of the fundamental frequency component, the second (and possibly the third) harmonic of a signal corresponding to binary all 0s and binary all 1s, is considered to be a perfectly adequate method of checking that the requirements of Table 9/G.703 have been met.

The relevant values are under study.

Note 2 – The masks given in Figure 22/G.703 and Figure 23/G.703 are for guidance purposes only and should not necessarily be used for measurement.

9.3 *Specifications at the input ports*

The digital signal presented at the input port should conform to Table 9/G.703 modified by the characteristics of the interconnecting coaxial pair.

The attenuation of the coaxial pair should be assumed to follow an approximate $\sqrt{f}$ law and to have a maximum insertion loss of 12 dB at a frequency of 70 MHz.

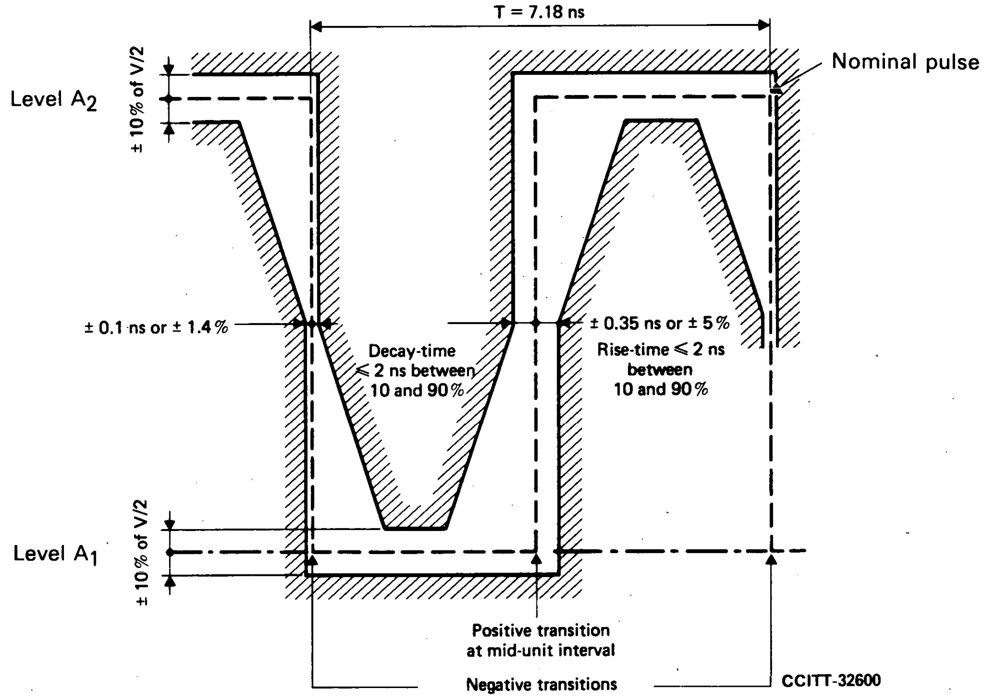
The return loss characteristics should be the same as that specified for the output port.

The input port shall be able to tolerate a digital signal with those electrical characteristics but modulated by sinusoidal jitter having an amplitude/frequency relationship defined by Figure 24/G.703. The equivalent binary content of the signal with jitter modulation shall be a $2^{23} - 1$ pseudo-random bit sequence as defined in the Recommendation cited in [2].

TABLE 9/G.703

Nominal pulse shape	Rectangular	
Pair(s) in each direction	One coaxial pair	
Test load impedance	75 ohms resistive	
Peak-to-peak voltage	1 ± 0.1 volt	
Overshoot	⩽ 5% of measured peak-to-peak voltage	
Rise time between 10% and 90% amplitudes of the measured amplitude	⩽ 2 ns	
Transition timing tolerance (referred to the mean value of the 50% amplitude points of negative transitions)	Negative transitions : ± 0.1 ns Positive transitions at unit interval boundaries : ± 0.5 ns Positive transitions at mid-unit interval : ± 0.35 ns	
Return loss	⩾ 15 dB over frequency range 7 MHz to 210 MHz	
Maximum peak-to-peak jitter at an output port (see Note)	Measured using a high-pass filter having a cut off frequency f_1 (see Figure 18/G.703) and a roll-off of 20 dB/decade	1.2 UI
	Measured using a high-pass filter having a cut off frequency f_3 (see Figure 18/G.703) and a roll-off of 20 dB/decade	0.06 UI

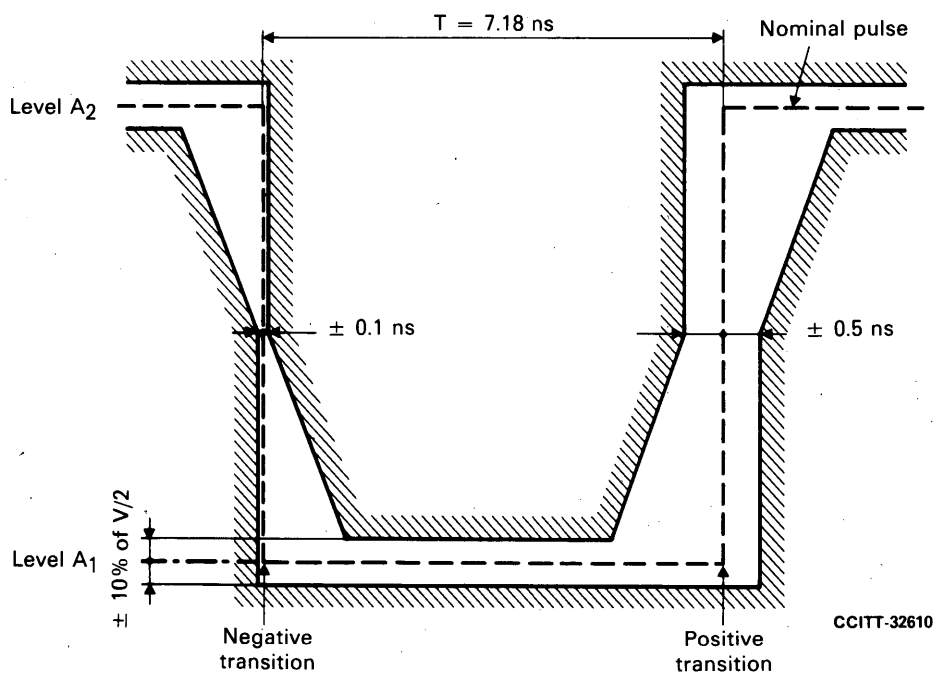
Note — The jitter values are of a provisional nature. They are correlated to the lower limit of maximum tolerable input jitter as specified in § 9.3. The details of the measurement method (time, probability, etc.) have to be further studied.



Note 1 – V is the nominal peak-to-peak amplitude.
Note 2 – The mask does not include the overshoot tolerance, see Table 9/G.703.

FIGURE 22/G.703

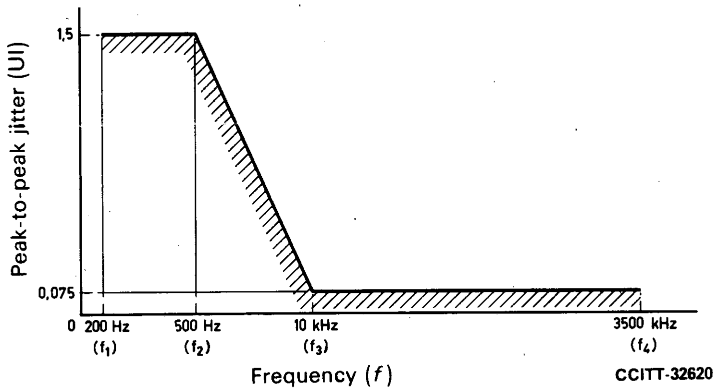
Mask of a pulse corresponding to a binary 0



Note 1 – The inverse pulse will have the same characteristics.
Note 2 – V is the nominal peak-to-peak amplitude.
Note 3 – The mask does not include the overshoot tolerance, see Table 9/G.703.

FIGURE 23/G.703

Mask of a pulse corresponding to a binary 1



Note – The outer conductor of the coaxial pair shall be connected to the earth at the input port and provision shall be made for connecting this conductor to earth, if required, at the input port.

FIGURE 24/G.703

Lower limit of maximum tolerable input jitter at 139 264 kbit/s

10 2048 kHz synchronization interface

10.1 *General*

The use of this interface is recommended for all applications where it is required to synchronize a digital equipment by an external 2048 kHz synchronization signal.

10.2 *Specifications at the output port (see Table 10/G.703)*

TABLE 10/G.703

Frequency	2048 kHz ± 50 ppm	
Pulse shape	The signal must conform with the mask (Figure 25/G.703) The value V corresponds to the maximum peak value The value V_1 corresponds to the minimum peak value	
Type of pair	Coaxial pair (see Note in § 10.3)	Symmetrical pair (see Note in § 10.3)
Test load impedance	75 ohms resistive	120 ohms resistive
Maximum peak voltage (V_{op})	1.5	1.9
Minimum peak voltage (V_{op})	0.75	1.0
Maximum jitter at an output port	Under study	

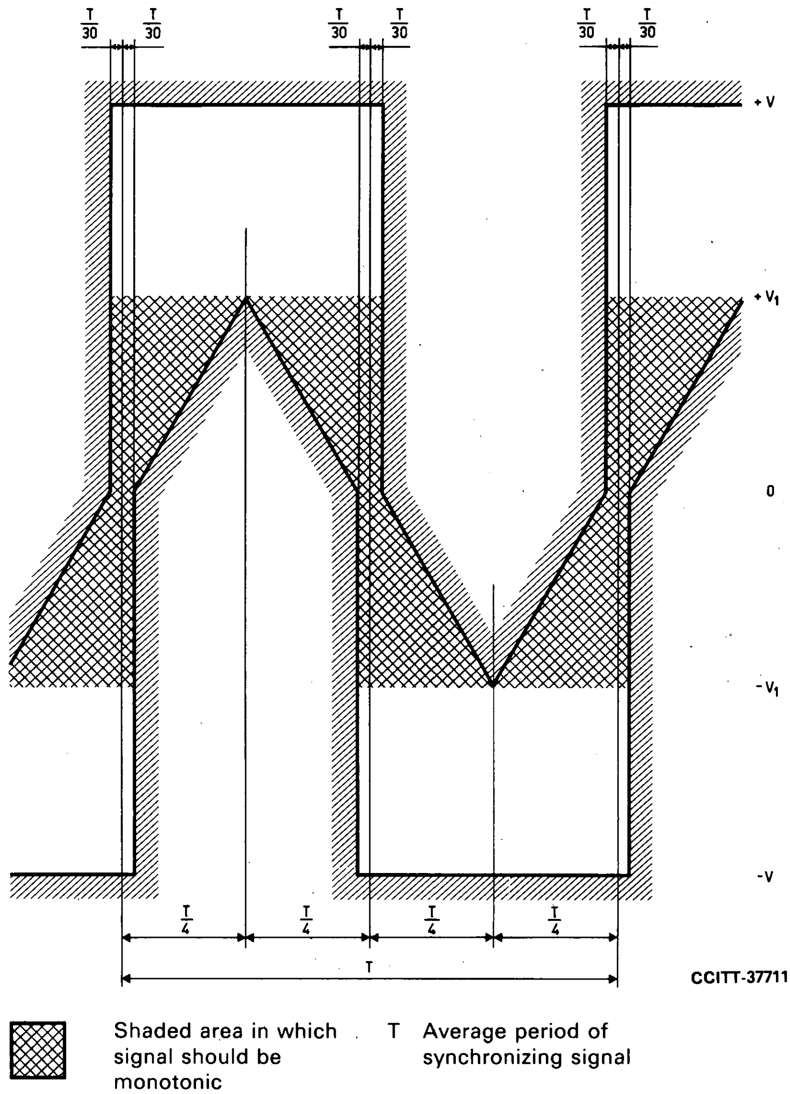


FIGURE 25/G.703

Wave shape at an output port

10.3 *Specifications at the input ports*

The signal presented at the input ports should be as defined above but modified by the characteristics of the interconnecting pair.

The attenuation of this pair shall be assumed to follow a $\sqrt{f}$ law and the loss at a frequency of 2048 kHz should be in the range 0 to 6 dB (minimum value). This attenuation should take into account any losses incurred by the presence of a digital distribution frame between the equipments.

The input port shall be able to tolerate a digital signal with these electrical characteristics but modulated by jitter. The jitter values are under study.

The return loss at 2048 kHz should be ⩾ 15 dB.

Note – The outer conductor of the coaxial pair or the screen of the symmetrical pair shall be connected to earth at the output port, and provision shall be made for connecting the outer conductor of the coaxial pair or the screen of the symmetrical pair to earth if required, at the input port.

ANNEX A

(to Recommendation G.703)

Definition of the HDB3 code

Coding of a binary signal into an HDB3 signal is done according to the following rules:

1) The HDB3 signal is pseudo-ternary; the three states are denoted B_+, B_- and 0.

2) Spaces in the binary signal are coded as spaces in the HDB3 signal. For strings of four spaces, however, special rules apply [see 4) below].

3) Marks in the binary signal are coded alternately as B_+ and B_- in the HDB3 signal (alternate mark inversion). Violations of the rule of alternate mark inversion are introduced when coding strings of four spaces [see 4) below].

4) Strings of four spaces in the binary signal are coded according to the following rules:

   a) The first space of a string is coded as a space if the preceding mark of the HDB3 signal has a polarity opposite to the polarity of the preceding violation and is not a violation by itself; it is coded as a mark, i.e. not a violation (i.e. B_+ or B_-), if the preceding mark of the HDB3 signal has the same polarity as that of the preceding violation or is by itself a violation.

      This rule ensures that successive violations are of alternate polarity so that no d.c. component is introduced.

   b) The second and third spaces of a string are always coded as spaces.

   c) The last space of a string of four is always coded as a mark, the polarity of which is such that it violates the rule of alternate mark inversion. Such violations are denoted V_+ or V_- according to their polarity.

ANNEX B

(to Recommendation G.703)

Correspondence between input and output jitter specifications at interfaces based on 2048-kbit/s hierarchy

For each interface, in the 2048-kbit/s based hierarchy, the specifications for output jitter have been derived from those for input jitter in order to ensure that, irrespective of the complexity of the digital path, the magnitude of maximum peak-to-peak jitter at the output port does not exceed the lower limit of maximum tolerable input peak-to-peak jitter at the corresponding input port. In accordance with this principle, for example, at 2048 kbit/s the output jitter at a G.703 interface should not exceed 1.5 UI for live traffic based measurements.

Studies have shown that a disparity exists when output jitter magnitudes are measured using pseudo-random pattern sequences and live traffic.

Although the exact correlation between these two conditions should be a subject for further study, the allowance margin between the peak-to-peak output jitter and the peak-to-peak input jitter as presently recommended in Recommendation G.703 for pseudo-random patterns (e.g. 1 to 1.5 for 2048 kbit/s) is assumed to be sufficient.

APPENDIX I

(to § 6 of the text)

Other solution concerning the 2048-kbit/s interface

TABLE I-1/G.703

Primary digital interfaces	
Bit rate	2048 kbit/s
Location	Equipment output port
Code	AMI + Timing
Pulse shape	Rectangular [a)]
Ratio of amplitude of positive pulses to amplitude of negative pulses at the centre of the pulse interval	0.95 to 1.05
Rise time and decay time between 10% and 90% of the pulse amplitude	⩽ 80 ns
Overshoot relative to the pulse amplitude	⩽ 10%
Pulse width	244 ± 30 ns at half amplitude
Peak voltage of pulse	3 V ± 10%
Peak voltage of space	Under study
Test load impedance	120 ohms resistive
Pairs in each direction of transmission	Two symmetric pairs

[a)] Pulse mask is under study.

APPENDIX II

(to § 7 of the text)

Another solution concerning the 8448-kbit/s interface

TABLE II-1/G.703

Second order digital interface	
Bit rate	8448 kbit/s
Location	Equipment output port
Code	AMI + Timing
Nominal pulse shape	Rectangular
Peak voltage	Under study
Peak voltage of space	Under study
Test load impedance	150 ohms resistive
Ratio of amplitude of positive pulses to amplitude of negative pulses	0.95 to 1.05
Rise time and decay time between 10% and 90% of the pulse amplitude	≤ 20 ns
Overshoot relative to the pulse amplitude	Under study
Pulse width	59 ± 6 ns
Pairs in each direction of transmission	Two symmetric pairs

References

[1] CCITT Recommendation *Specification for instrumentation to measure bir-error ratio on digital systems,* Vol. IV, Fascicle IV.4, Rec. O.151, § 2.1 and Tables 1/O.151 and 2/O.151.

[2] *Ibid.*, § 2.2 and Table 2/O.151.

MAINTENANCE OF DIGITAL NETWORKS

(Geneva, 1980)

1 General

A maintenance philosophy for integrated digital networks has been defined. The intent of the philosophy is to allow maintenance personnel to efficiently identify failed equipment, restore service and repair the failed equipment. To this end, a maintenance entity and maintenance and service alarm indications and the means to assist in locating failures have been defined.

It is important that coherent maintenance principles are applied to the various constituent parts of digital networks (e.g. multiplexers, transmission systems, exchanges, etc.) so that satisfactory equipment interworking is guaranteed, unambiguous fault location is possible and unnecessary activities can be avoided.

The principles outlined below have been applied to the Recommendations for digital equipments; new and future Recommendations should also take these principles into account.

This Recommendation is also intended to serve as a guide to Study Groups and organizations who have not actively been engaged in the preparation of the Recommendations for digital equipments and to assist them in understanding the purpose of capabilities called for and the terminologies used.

It is recognized that the maintenance principles outlined below are not complete. These principles cover many transmission aspects and some, but not all, switching aspects; traffic and network management aspects have not yet been considered. Furthermore, automatic maintenance methods using stored programme controlled support systems have not been included either.

The foregoing matters are the subject of further studies aimed at expanding these maintenance principles.

2 Maintenance entity

2.1 To facilitate the presentation of a maintenance philosophy, it is convenient to assume that the different equipment elements of such networks are interconnected at easily identifiable points at which the interface conditions defined for these equipments apply. Such points may be provided by digital distribution frames (see, for example, Recommendation G.703). Even in a station where no digital distribution frame is provided, an equivalent point where defined interface conditions apply will normally be identifiable.

2.2 The equipments which occur between two consecutive distribution frames, or their equivalents, constitute a maintenance entity. This is illustrated in Figure 1/G.704. A maintenance entity may be composed of digital switching equipment, digital multiplexing equipment, a digital line section or a digital radio section but not any combination of different elements (see Figure 1/G.704).

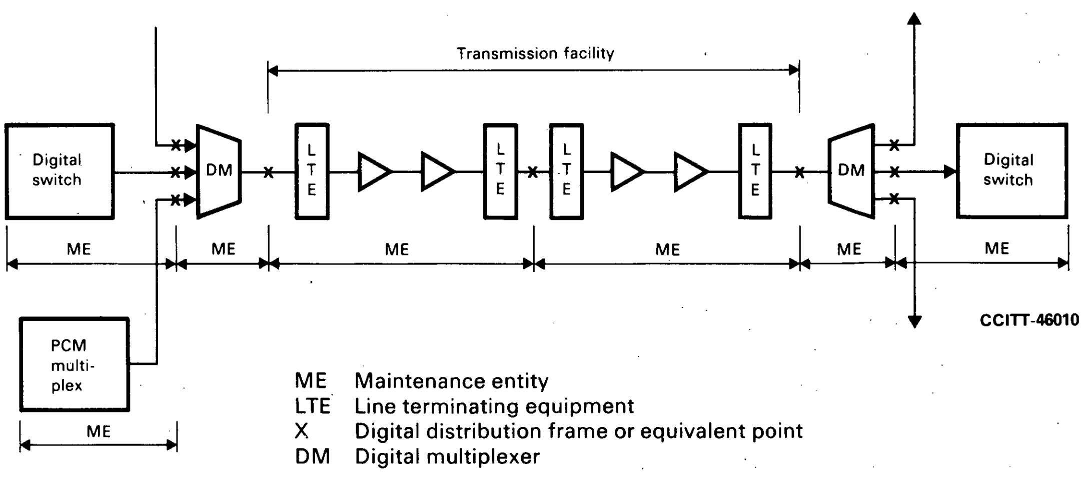


FIGURE 1/G.704

Maintenance entity concept

3 Maintenance principles

3.1 When a fault occurs within a network, it is desirable that maintenance alarm indications appear at the failed maintenance entity. In the case where this is not practicable, the alarm indication should occur at the closest possible entity. This is the main principle.

3.2 A further important principle is that, where possible, a maintenance alarm indication in an entity should not cause a related alarm indication at other entities. In the event that such alarm indications are permitted to occur they should clearly indicate that the failure lies upstream, and not in the other entities displaying the indications.

3.3 Meeting these two principles ensures that the responsible maintenance personnel are called into action, and that usually no unnecessary maintenance activity is initiated elsewhere.

4 Alarm indications and consequent actions

Detection of faults within a network is accomplished by having suitable performance monitors and alarm indications associated with each maintenance entity. The performance at maintenance limits and its relation to that of the design objectives etc. is illustrated in Figure 1/G.102 [1].

The following alarm indications should be generated at maintenance entities. The location and provision of any visual and/or audible alarm activated by these alarm indications is left to the discretion of each Administration.

4.1 *A prompt maintenance alarm indication* is generated at maintenance entities in order to initiate maintenance activities by maintenance personnel to remove from service a defective maintenance entity for the purpose of restoring good service and effecting repair of the failed maintenance entity.

The standard for activating the prompt alarm indication at a maintenance entity will generally be based on the requirements of the telephony service.

4.2 *A deferred maintenance alarm indication* is generated when immediate action is not required by maintenance personnel, e.g. when performance falls below other higher standards but the effect does not warrant removal from service, or if automatic changeover to standby equipment has been used to restore service.

4.3 *A service alarm indication* is generated at maintenance entities at which the service originates and/or terminates to indicate that the particular service is no longer available (e.g. when a primary block is no longer available for setting up connections, the PCM muldex will extend a service alarm indication to the exchange equipment).

The service alarm indication should be generated when performance falls below a level specified for a particular service. This level may coincide with that for initiating also a prompt maintenance alarm.

4.4 The following strategy for initiating manual or automatic (if implemented) restoral on an entity basis is recommended.

a) If a fault occurs either in maintenance entities without automatic changeover capabilities or with automatic changeover capabilities but no standby available, the following actions should be executed:

   1) Initiate a prompt maintenance alarm indication at the maintenance entity containing the failed equipment.

   2) Transmit an Alarm Indication Signal (AIS) in the direction affected (downstream direction) or give an Upstream Failure Indication (UFI) at equipment which has not failed.

   3) Initiate a service alarm indication at the appropriate entities e.g. primary PCM multiplex or digital switch interfaces. (As a consequence the circuits may be removed from service.)

b) If a fault occurs in a maintenance entity having automatic changeover capability with a standby available, the following actions should be automatically executed:

   1) Changeover to the standby.

   Note – Whether or not connections are released as a result of automatic changeover depends on the service performance objectives assigned to each maintenance entity.

2) Initiate a deferred maintenance alarm indication at the maintenance entity containing the failed equipment.

4.5 *Restoral of service by switching on a path basis* (further study)

Note – The possibility of restoring part or all of the released connections on a per call basis requires further study. This could be performed either by the maintenance entity where the failure has occurred or by another maintenance entity.

5 Upstream failures

Provision may be made at a maintenance entity to indicate an upstream failure and/or inhibit unnecessary actions. This can be accomplished in one of two ways:

5.1 *Alarm indication signal (AIS)*

An alarm indication signal (AIS) is a signal associated with a prompt maintenance alarm of a defective maintenance entity and is, when possible, transmitted in the direction affected (downstream direction) as a substitute for the normal signal, indicating to other nondefective entities that a failure has been identified and that other maintenance alarms consequent to this failure should be inhibited. The binary equivalent of the AIS corresponds to an all 1s signal.

Note 1 – The AIS is different from the "alarm indication to the remote end"; see for example Recommendation G.732, § 3.2.3.

Note 2 – The AIS capability does not impose any restrictions on the binary content of signals which may be transmitted over the digital hierarchy at the primary multiplex and higher levels. The implications at the 64-kbit/s level and at lower bit rates are under study, since ambiguity arises between AIS and an all 1s information signal.

5.2 *Upstream failure indication*

The upstream failure indication UFI given by a maintenance entity indicates that the signal arriving at that maintenance entity is defective. The UFI indicates that the fault has occurred upstream of this point, and no unnecessary maintenance activities are initiated.

The appearance of an alarm indicates either a failure in the equipment generating the alarm or a failure of the incoming signal (an upstream failure). To distinguish between these two possibilities it is necessary to provide an independent test, either of the input signal, or of the equipment generating the alarm. The input signal can be checked for proper parity, for example, by a monitor included in the protection switching equipment. A defective input signal indicates an upstream failure. Alternatively, the equipment generating the alarm can be tested independently, by looping, for example, and if the equipment operates correctly, an upstream failure is indicated.

Reference

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

Recommendation G.705

INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

(Geneva, 1980)

The CCITT,

considering

(a) the measure of agreement that has so far been reached in the studies of Integrated Digital Networks (IDNs) dedicated to specific services such as telephony, data and also of an Integrated Services Digital Network (ISDN),

(b) the need for a common basis for the future studies necessary for the evolution towards an ISDN, *recommends*

that the ISDN should be based on the following conceptual principles:

(1) The ISDN will be based on and evolve from the telephony IDN by progressively incorporating additional functions and network features including those of any other dedicated networks so as to provide for existing and new services.

(2) New services introduced into the ISDN should be arranged to be compatible with 64-kbit/s switched digital connections.

(3) The transition from the existing networks to a comprehensive ISDN may require a period of time extending over one or two decades.

(4) During the transition period arrangements must be developed for the interworking of services on ISDNs and services on other networks.

(5) The ISDN will contain intelligence for the purpose of providing service features, maintenance and network management functions. This intelligence may not be sufficient for some new services and may have to be supplemented by either additional intelligence within the network, or possibly compatible intelligence in the customer terminals.

(6) A layered functional set of protocols appears desirable for the various access arrangements to the ISDN. Access from the customer to ISDN resources may vary depending upon the service required and on the status of evolution of national ISDNs.

Note – Existing relevant Recommendations for some of the constituent elements of the ISDN are contained in Series G, O, Q and X Recommendations and also in relevant volumes of the CCIR.

7.1 Coding of analogue signals

Recommendation G.711

PULSE CODE MODULATION (PCM) OF VOICE FREQUENCIES

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 General

The characteristics given below are recommended for encoding voice-frequency signals.

2 Sampling rate

The nominal value recommended for the sampling rate is 8000 samples per second. The tolerance on that rate should be ± 50 parts per million (ppm).

3 Encoding law

3.1 Eight binary digits per sample should be used for international circuits.

3.2 Two encoding laws are recommended and these are commonly referred to as the A-law and the μ-law. The definition of these laws is given in Tables 1a/G.711 and 1b/G.711 and Tables 2a/G.711 and 2b/G.711 respectively.

When using the μ-law in networks where suppression of the all 0 character signal is required, the character signal corresponding to negative input values between decision values numbers 127 and 128 should be 00000010 and the value at the decoder output is −7519. The corresponding decoder output value number is 125.

3.3 The number of quantized values results from the encoding law.

3.4 Digital paths between countries which have adopted different encoding laws should carry signals encoded in accordance with the A-law. Where both countries have adopted the same law, that law should be used on digital paths between them. Any necessary conversion will be done by the countries using the μ-law.

3.5 The rules for conversion are given in Tables 3/G.711 and 4/G.711.

4 Relationship between the encoding laws and the audio level

The relationship between the encoding laws of Tables 1/G.711 and 2/G.711 and the audio signal level is defined as follows:

A sine-wave signal of 1 kHz at a nominal level of 0 dBm0 should be present at any voice frequency output of the PCM multiplex when the periodic sequence of character signals of Table 5/G.711 for the A-law and of Table 6/G.711 for the μ-law is applied to the decoder input.

The resulting theoretical load capacity (T_{max}) is +3.14 dBm0 for the A-law, and +3.17 dBm0 for the μ-law.

TABLE 1a / G.711

A-law, positive input values

1	2	3	4	5	6	7	8
Segment number	Number of intervals × interval size	Value at segment end points	Decision value number n	Decision value x_n (see Note 1)	Character signal before inversion of the even bits Bit number 1 2 3 4 5 6 7 8	Value at decoder output y_n (see Note 3)	Decoder output value number
		4096	(128)	(4096)			
					1 1 1 1 1 1 1 1	4032	128
7	16 × 128		127	3968	(see Note 2)		
			113	2176			
					1 1 1 1 0 0 0 0	2112	113
		2048	112	2048			
6	16 × 64				(see Note 2)		
			97	1086			
					1 1 1 0 0 0 0 0	1056	97
		1024	96	1024			
5	16 × 32				(see Note 2)		
			81	544			
					1 1 0 1 0 0 0 0	528	81
		512	80	512			
4	16 × 16				(see Note 2)		
			65	272			
					1 1 0 0 0 0 0 0	264	65
		256	64	256			
3	16 × 8				(see Note 2)		
			49	136			
					1 0 1 1 0 0 0 0	132	49
		128	48	128			
2	16 × 4				(see Note 2)		
			33	68			
					1 0 1 0 0 0 0 0	66	33
		64	32	64			
1 ↓	32 × 2				(see Note 2)		
			1	2			
					1 0 0 0 0 0 0 0	1	1
			0	0			

Note 1 – 4096 normalized value units correspond to T_{max} = 3.14 dBm0.

Note 2 – The character signals are obtained by inverting the even bits of the signals of column 6. Before this inversion, the character signal corresponding to positive input values between two successive decision values numbered n and $n + 1$ (see column 4) is (128 + n) expressed as a binary number

Note 3 – The value at the decoder output is $y_n = \frac{x_{n-1} + x_n}{2}$ for n = 1, ..., 127, 128.

Note 4 – x_{128} is a virtual decision value.

TABLE 1b / G.711

A-law, negative input values

1	2	3	4	5	6	7	8
Segment Number	Number of intervals × interval size	Value at segment end points	Decision value number n	Decision value x_n (see Note 1)	Character signal before inversion of the even bits Bit number 1 2 3 4 5 6 7 8	Value at decoder output y_n (see Note 3)	Decoder output value number
			0	0			
					0 0 0 0 0 0 0 0	–1	1
			1	–2			
1	32 × 2		⋮	⋮	(see Note 2)	⋮	⋮
		–64	32	–64			
					0 0 1 0 0 0 0 0	–66	33
2	16 × 4		33	–68	(see Note 2)	⋮	⋮
		–128	48	–128			
					0 0 1 1 0 0 0 0	–132	49
3	16 × 8		49	–136	(see Note 2)	⋮	⋮
		–256	64	–256			
					0 1 0 0 0 0 0 0	–264	65
4	16 × 16		65	–272	(see Note 2)	⋮	⋮
		–512	80	–512			
					0 1 0 1 0 0 0 0	–528	81
5	16 × 32		81	–544	(see Note 2)	⋮	⋮
		–1024	96	–1024			
					0 1 1 0 0 0 0 0	–1056	97
6	16 × 64		97	–1088	(see Note 2)	⋮	⋮
		–2048	112	–2048			
					0 1 1 1 0 0 0 0	–2112	113
7	16 × 128		113	–2176	(see Note 2)	⋮	⋮
			127	–3968			
					0 1 1 1 1 1 1 1	–4032	128
		–4096	(128)	(–4096)			

Note 1 – 4096 normalized value units correspond to T_{max} = 3.14 dBm0.

Note 2 – The character signals are obtained by inverting the even bits of the signals of column 6. Before this inversion, the character signal corresponding to negative input values between two successive decision values numbered n and $n + 1$ (see column 4) is n expressed as a binary number.

Note 3 – The value at the decoder output is $y_n = \frac{x_{n-1} + x_n}{2}$ for n = 1, ..., 127, 128.

Note 4 – x_{128} is a virtual decision value.

TABLEAU 2a / G.711

μ-law, positive input values

1	2	3	4	5	6	7	8
Segment number	Number of intervals × interval size	Value at segment end points	Decision value number n	Decision value x_n (see Note 1)	Character signal Bit number 1 2 3 4 5 6 7 8	Value at decoder output y_n (see Note 3)	Decoder output value number
		8159	(128)	(8159)			
					1 0 0 0 0 0 0 0	8031	127
8	16 × 256		127	7903	(see Note 2)		
			113	4319			
					1 0 0 0 1 1 1 1	4191	112
7	16 × 128	4063	112	4063	(see Note 2)		
			97	2143			
					1 0 0 1 1 1 1 1	2079	96
6	16 × 64	2015	96	2015	(see Note 2)		
			81	1055			
					1 0 1 0 1 1 1 1	1023	80
5	16 × 32	991	80	991	(see Note 2)		
			65	511			
					1 0 1 1 1 1 1 1	495	64
4	16 × 16	479	64	479	(see Note 2)		
			49	239			
					1 1 0 0 1 1 1 1	231	48
3	16 × 8	223	48	223	(see Note 2)		
			33	103			
					1 1 0 1 1 1 1 1	99	32
2	16 × 4	95	32	95	(see Note 2)		
			17	35			
					1 1 1 0 1 1 1 1	33	16
1	15 × 2	31	16	31	(see Note 2)		
			2	3			
					1 1 1 1 1 1 1 0	2	1
	1 × 1		1	1			
					1 1 1 1 1 1 1 1	0	0
			0	0			

Note 1 – 8159 normalized value units correspond to T_{max} = 3.17 dBm0.

Note 2 – The character signal corresponding to positive input values between two successive decision values numbered n and $n + 1$ (see column 4) is $(255 - n)$ expressed as a binary number.

Note 3 – The value at the decoder output is $y_0 = x_0 = 0$ for $n = 0$, and $y_n = \frac{x_n + x_{n+1}}{2}$ for $n = 1, 2, ..., 127$.

Note 4 – x_{128} is a virtual decision value.

TABLE 2b / G.711

μ-law, negative input values

1	2	3	4	5	6	7	8
Segment number	Number of intervals × interval size	Value at segment end points	Decision value number n	Decision value x_n (see Note 1)	Character signal Bit number 1 2 3 4 5 6 7 8	Value at decoder output y_n (see Note 3)	Decoder output value number
1	1 × 1		0	0			
					0 1 1 1 1 1 1 1	0	0
			1	−1			
	15 × 2				0 1 1 1 1 1 1 0	−2	1
			2	−3			
					(see Note 2)		
		−31	16	−31			
2	16 × 4				0 1 1 0 1 1 1 1	−33	16
			17	−35			
					(see Note 2)		
		−95	32	−95			
3	16 × 8				0 1 0 1 1 1 1 1	−99	32
			33	−103			
					(see Note 2)		
		−223	48	−223			
4	16 × 16				0 1 0 0 1 1 1 1	−231	48
			49	−239			
					(see Note 2)		
		−479	64	−479			
5	16 × 32				0 0 1 1 1 1 1 1	−495	64
			65	−511			
					(see Note 2)		
		−991	80	−991			
6	16 × 64				0 0 1 0 1 1 1 1	−1023	80
			81	−1055			
					(see Note 2)		
		−2015	96	−2015			
7	16 × 128				0 0 0 1 1 1 1 1	−2079	96
			97	−2143			
					(see Note 2)		
		−4063	112	−4063			
8	16 × 256				0 0 0 0 1 1 1 1	−4191	112
			113	−4319			
					(see Note 2)		
			126	−7647			
					0 0 0 0 0 0 0 1	−7775	126
			127	−7903			
					0 0 0 0 0 0 0 0	−8031	127
		−8159	(128)	(−8159)			

Note 1 – 8159 normalized value units correspond to T_{max} = 3.17 dBm0.

Note 2 – The character signal corresponding to negative input values between two successive decision values numbered n and n + 1 (see column 4) is (127 – n) expressed as a binary number for n = 0, 1, ..., 127.

Note 3 – The value at the decoder output is $y_0 = x_0 = 0$ for n = 0, and $y_n = \frac{x_n + x_{n+1}}{2}$ for n = 1, 2, ..., 127.

Note 4 – x_{128} is a virtual decision value.

TABLE 3/G.711

μ-A conversion

μ-law Decoder output value number	*A-law* Decoder output value number	*μ-law* Decoder output value number	*A-law* Decoder output value number
0	1	44	41
1	1	45	42
2	2	46	43
3	2	47	44
4	3	48	46
5	3	49	48
6	4	50	49
7	4	51	50
8	5	52	51
9	5	53	52
10	6	54	53
11	6	55	54
12	7	56	55
13	7	57	56
14	8	58	57
15	8	59	58
16	9	60	59
17	10	61	60
18	11	62	61
19	12	63	62
20	13	64	64
21	14	65	65
22	15	66	66
23	16	67	67
24	17	68	68
25	18	69	69
26	19	70	70
27	20	71	71
28	21	72	72
29	22	73	73
30	23	74	74
31	24	75	75
32	25	76	76
33	27	77	77
34	29	78	78
35	31	79	79
36	33	80	80
37	34	81	82
38	35	82	83
39	36	83	84
40	37	84	85
41	38	85	86
42	39	86	87
43	40	87	88
		.	.
		.	.
		.	.
		127	128

Note – The input signals to an A-law decoder will normally include even bit inversion as applied in accordance with Note 2 of Table 1a/G.711. Consequently the output signals from a μ-A converter should have even bit inversion embodied within the converter output.

TABLE 4 / G.711

A-μ conversion

A-law Decoder output value number	*μ-law* Decoder output value number	*A-law* Decoder output value number	*μ-law* Decoder output value number
1	1	51	52
2	3	52	53
3	5	53	54
4	7	54	55
5	9	55	56
6	11	56	57
7	13	57	58
8	15	58	59
9	16	59	60
10	17	60	61
11	18	61	62
12	19	62	63
13	20	63	64
14	21	64	64
15	22	65	65
16	23	66	66
17	24	67	67
18	25	68	68
19	26	69	69
20	27	70	70
21	28	71	71
22	29	72	72
23	30	73	73
24	31	74	74
25	32	75	75
26	32	76	76
27	33	77	77
28	33	78	78
29	34	79	79
30	34	80	80
31	35	81	80
32	35	82	81
33	36	83	82
34	37	84	83
35	38	85	84
36	39	86	85
37	40	87	86
38	41	88	87
39	42	89	88
40	43	90	89
41	44	91	90
42	45	92	91
43	46	93	92
44	47	94	93
45	48	95	94
46	48	96	95
47	49	97	96
48	49	98	97
49	50	.	.
50	51	.	.
		.	.
		128	127

Note – The output signals to an A-law encoder will have had even bit inversion applied within the encoder in accordance with Note 2 of Table 1a/G.711. Consequently the input signals to an Aμ converter will already be in this state, so that removal of even bit inversion should be embodied within the converter.

TABLE 5/G.711

A-law							
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
0	0	1	1	0	1	0	0
0	0	1	0	0	0	0	1
0	0	1	0	0	0	0	1
0	0	1	1	0	1	0	0
1	0	1	1	0	1	0	0
1	0	1	0	0	0	0	1
1	0	1	0	0	0	0	1
1	0	1	1	0	1	0	0

TABLE 6/G.711

μ-law							
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
0	0	0	1	1	1	1	0
0	0	0	0	1	0	1	1
0	0	0	0	1	0	1	1
0	0	0	1	1	1	1	0
1	0	0	1	1	1	1	0
1	0	0	0	1	0	1	1
1	0	0	0	1	0	1	1
1	0	0	1	1	1	1	0

Recommendation G.712

PERFORMANCE CHARACTERISTICS OF PCM CHANNELS AT AUDIO FREQUENCIES

(Geneva, 1972; amended at Geneva, 1976 and 1980)

The CCITT

recommends

that the performance characteristics which follow should be met between the audio-frequency ports of PCM channels coded in accordance with Recommendation G.711.

The performance limits quoted are to be considered as recommendations to be met in all cases.

The values and limits specified are those which should be obtained in 4-wire measurements using two PCM multiplex terminal equipments connected back-to-back (except for § 4.3 below) and with the input and output ports of the channels terminated with their nominal impedance.

Further study is required for the method of measurement of the send and the receive sides separately.

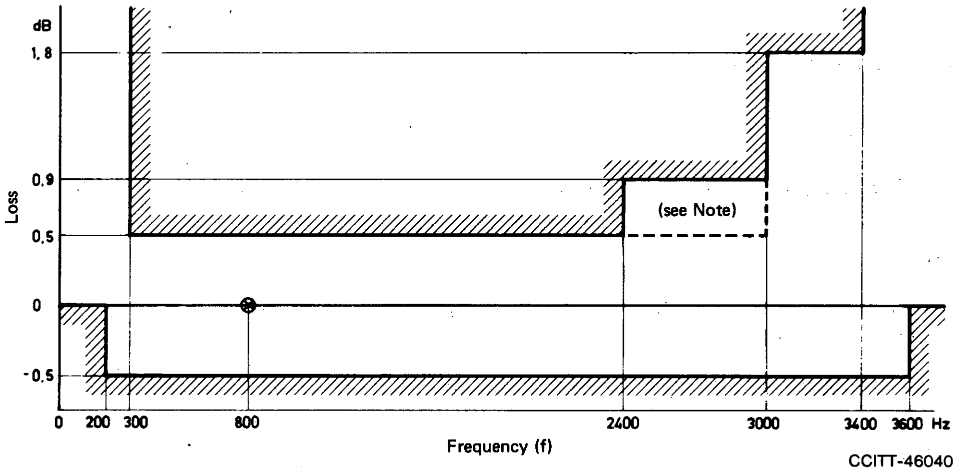
1 Attenuation/frequency distortion

The variations with frequency of the attenuation of any channel should lie within the limits shown in the mask of Figure 1/G.712.

The reference frequency is 800 Hz.

The input power level should be 0 dBm0.

The distortion contributed by the separate send and receive sides of the equipment should be nominally equal.



Note – In some applications in which several PCM channels may be connected in tandem, it may be necessary to extend the + 0.5 dB-limit from 2400 Hz to 3000 Hz.

FIGURE 1/G.712

Attenuation/frequency distortion

2 Envelope delay

2.1 *Absolute envelope delay*

The absolute envelope delay at the frequency of minimum envelope delay should not exceed 600 microseconds (provisional value).

The minimum value of envelope delay is taken as the reference for the envelope delay distortion.

2.2 *Envelope delay distortion with frequency*

The envelope delay distortion should lie within the limits shown in the template of Figure 2/G.712.

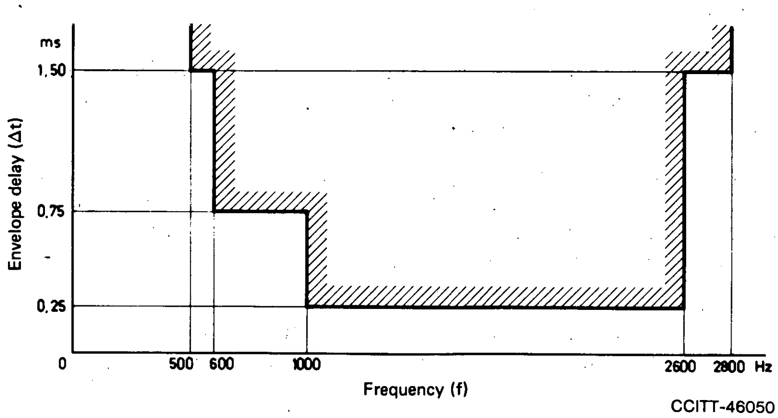


FIGURE 2/G.712

Envelope delay distortion with frequency

2.3 *Input level*

The requirements of §§ 2.1 and 2.2 above should be met at an input power level of 0 dBm0.

3 Impedance of audio-frequency ports

3.1 *Nominal impedance*

The nominal impedance at the 4-wire audio input and output ports should be 600 ohms, balanced.

3.2 *Return loss*

The return loss, measured against the nominal impedance, should not be less than 20 dB over the frequency range 300 to 3400 Hz.

Note – The return loss limit should be met when the adjusting pads are set to 0 dB [1].

3.3 *Longitudinal balance*

Under study.

4 Idle channel noise

4.1 *Weighted noise*

With the input and output ports of the channel terminated in the nominal impedance, the idle channel noise should not exceed –65 dBm0p.

4.2 *Single frequency noise*

The level of any single frequency (in particular the sampling frequency and its multiples), measured selectively, should not exceed –50 dBm0.

4.3 *Receiving equipment noise*

Noise contributed by the receiving equipment alone should be less than –75 dBm0p when its input is driven by a PCM signal corresponding to the decoder output value number 0 for the μ-law or decoder output value number 1 for the A-law.

5 Discrimination against out-of-band input signals

5.1 With any sine-wave signal in the range 4.6-7.2 kHz applied to the input port of the channel at a suitable level, the level of any image frequency produced at the output port of the channel should, as a minimum requirement, be at least 25 dB below the level of the test signal.

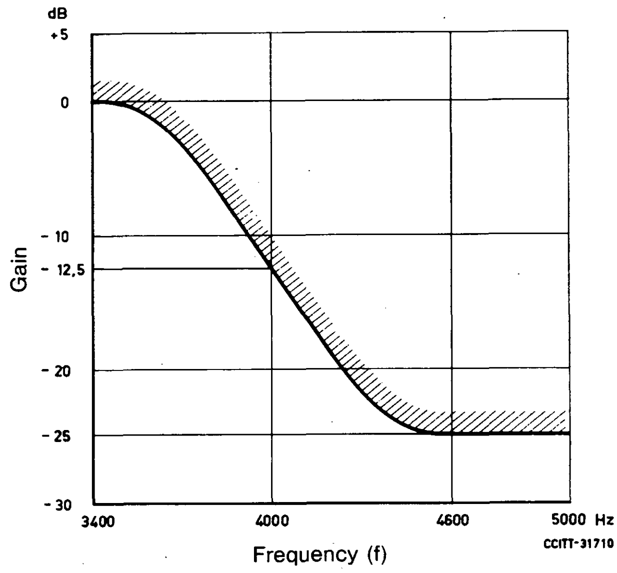
5.2 Under the most adverse conditions encountered in a national network, the PCM channel should not contribute more than 100 pW0p of additional noise in the band 0-4 kHz at the channel output, as a result of the presence of out-of-band signals at the channel input.

Note 1 – The discrimination required depends on the performance of FDM channel equipments and telephone instruments in national networks and individual Administrations should carefully consider the requirements they should specify, taking into account the comments above and the requirement of § 5.2 above. In all cases at least the minimum requirement of § 5.1 above should be met.

Note 2 – Attention is drawn to the importance of the attenuation characteristic in the range 3400 to 4600 Hz. Although other attenuation characteristics can satisfy the requirements §§ 5.1 and 5.2 above, the filter template of Figure 3/G.712 gives adequate protection against the out-of-band signals.

6 Spurious out-of-band signals at the channel output

6.1 With any sine-wave signal in the range 300-3400 Hz at a level of 0 dBm0 applied to the input port of a channel, the level of spurious out-of-band image signals measured selectively at the output port should be lower than –25 dBm0.



Note – The curved portion of the graph conforms to the equation $G = 12.5 \left[\sin \frac{\pi(4000 - f)}{1200} - 1\right]$ dB for the range $3400 \leqslant f \leqslant 4600$.

FIGURE 3/G.712

Gain relative to gain at 800Hz

6.2 The spurious out-of-band signals should not give rise to unacceptable interference in equipment connected to the PCM channel. In particular, the intelligible or unintelligible crosstalk in a connected FDM channel should not exceed a level of −65 dBm0 as a consequence of the spurious out-of-band signals at the PCM channel output.

Note 1 – The discrimination required depends on the performance of FDM channel equipment and telephone instruments in national networks and individual Administrations should carefully consider the requirements they should specify, taking into account the comments above and the requirement of § 6.2 above. In all cases at least the minimum requirement of § 6.1 above should be met.

Note 2 – Attention is drawn to the importance of the attenuation characteristic in the range 3400 to 4600 Hz. Although other attenuation characteristics can satisfy the requirements §§ 6.1 and 6.2 above, the filter template of Figure 3/G.712 gives adequate protection against the out-of-band signals.

7 Intermodulation

7.1 Two sine-wave signals of different frequencies f_1 and f_2 not harmonically related, in the range 300-3400 Hz and of equal levels in the range −4 to −21 dBm0, applied simultaneously to the input port of a channel should not produce any $2f_1 - f_2$ intermodulation product having a level greater than −35 dB relative to the level of one of the two input signals.

7.2 A signal having a level of −9 dBm0 at any frequency in the range 300-3400 Hz and a signal of 50 Hz at a level of −23 dBm0 applied simultaneously to the input port should not produce any intermodulation product of a level exceeding −49 dBm0.

Note – These requirements are in practice always met if the requirements according to §§ 8 and 10 are met.

8 Total distortion, including quantizing distortion

Two alternative methods are recommended.

Method 1

With a suitable noise signal applied to the input port of a channel, the ratio of signal-to-total distortion power measured at the output port should lie above the limits shown in Figure 4/G.712.

Note 1 – These limits are based on a noise signal having a gaussian distribution of amplitudes and the derivation of the limits is given in Annex A.

Note 2 – Appropriate corrections must be made depending on the characteristics of the test apparatus in order that the results of measurements may be related correctly to the specified limits (see Recommendation O.131 [2] concerning the basic specification clauses for a quantizing distortion measuring apparatus giving a pseudo-random noise stimulus).

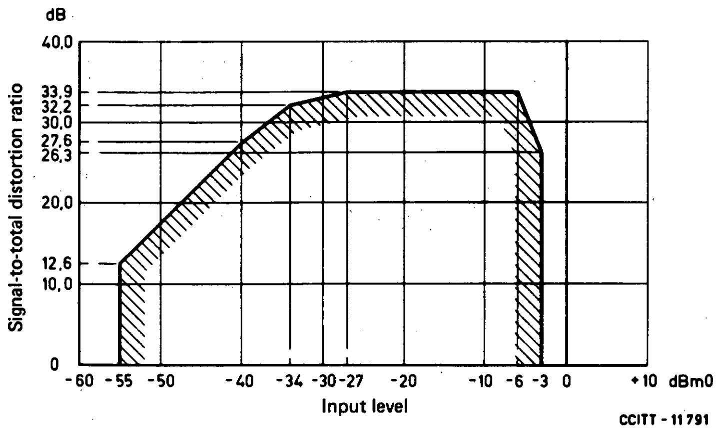


FIGURE 4/G.712

Signal-to-total distortion ratio as a function of input level (Method 1)

Method 2

With a sine-wave signal in the frequency range 700-1100 Hz (excluding submultiples of 8 kHz) or within the frequency range 350-550 Hz (preferably 420 ± 20 Hz but excluding submultiples of 8 kHz) applied to the input port of a channel, the ratio of signal-to-total distortion power measured with the proper noise weighting (see the Recommendation cited in [3]), should lie above the limits shown in Figure 5/G.712.

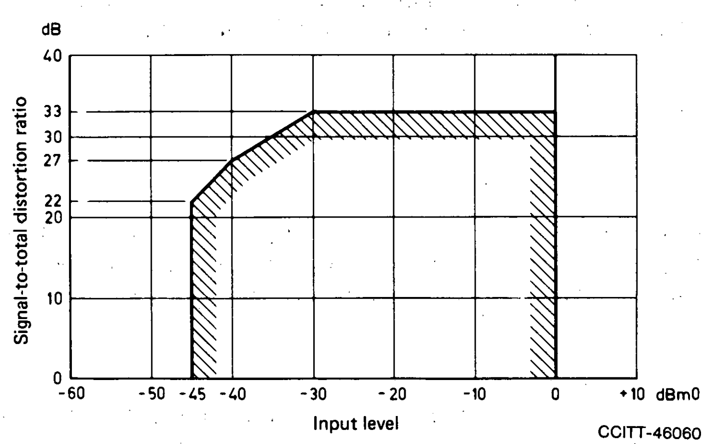


FIGURE 5/G.712

Signal-to-total distortion ratio as a function of input level (Method 2)

9 Spurious in-band signals at the channel output port

With a sine-wave signal in the frequency range 700-1100 Hz (excluding submultiples of 8 kHz) and at a level of 0 dBm0 applied to the input port of a channel, the output level at any frequency other than the frequency of the applied signal, measured selectively in the frequency band 300-3400 Hz, should be less than −40 dBm0.

10 Variation of gain with input level

Two alternative methods are recommended.

Method 1

With a suitable noise signal applied to the input of any channel at a level between −60 dBm0 and −10 dBm0, the gain variation of that channel, relative to the gain at an input level of −10 dBm0, should lie within the limits of the mask of Figure 6a/G.712.

Furthermore, with a sine-wave signal in the frequency range 700-1100 Hz (excluding submultiples of 8 kHz) applied to the input port of any channel at a level between −10 dBm0 and +3 dBm0, the gain variation of that channel relative to the gain at an input level of −10 dBm0, should lie within the limits of the mask of Figure 6b/G.712.

Method 2

With a sine-wave signal in the frequency range 700-1100 Hz (excluding submultiples of 8 kHz) applied to the input port of any channel at a level between −55 dBm0 and +3 dBm0, the gain variation of that channel relative to the gain at an input level of −10 dBm0, should lie within the limits of the mask of Figure 6c/G.712.

11 Interchannel crosstalk

11.1 The crosstalk between individual channels of a multiplex should be such that with a sine-wave signal in the frequency range 700-1100 Hz (excluding submultiples of 8 kHz) and a level of 0 dBm0 applied to an input port, the crosstalk level received in any other channel should not exceed −65 dBm0.

11.2 When a white noise signal shaped in accordance with Recommendation G.227 [4] at a level of 0 dBm0 is applied to the input port of up to four channels, the level of the crosstalk received in any other channel should not exceed −60 dBm0p. Uncorrelated noise should be used when more than one input channel is energized.

12 Go-to-return crosstalk

The near-end signal to crosstalk ratio between one channel and its associated return channel should be better than 60 dB when using a sine-wave signal at 0 dBm0 at any frequency in the range 300-3400 Hz.

13 Interference from signalling

The maximum level of any interference into a channel should not exceed −60 dBm0p when signalling is active simultaneously on all channels.

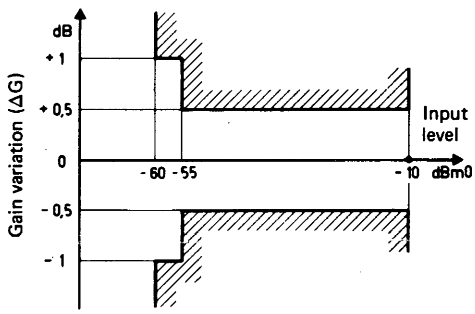
14 Relative levels at input and output

The specifications should conform to the Recommendation cited in [5].

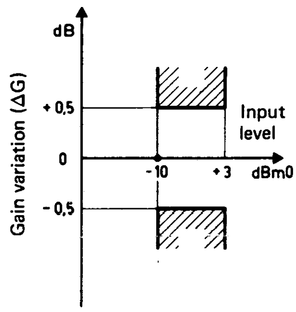
15 Short-term and long-term stability

When a sine-wave signal at a level of 0 dBm0 is applied to any audio-frequency input, the level measured at the corresponding audio frequency output should not vary by more than ± 0.2 dB during any 10-minute interval of typical operation, nor by more than ± 0.5 dB during any one year under the permitted variations in the power supply voltage and temperature.

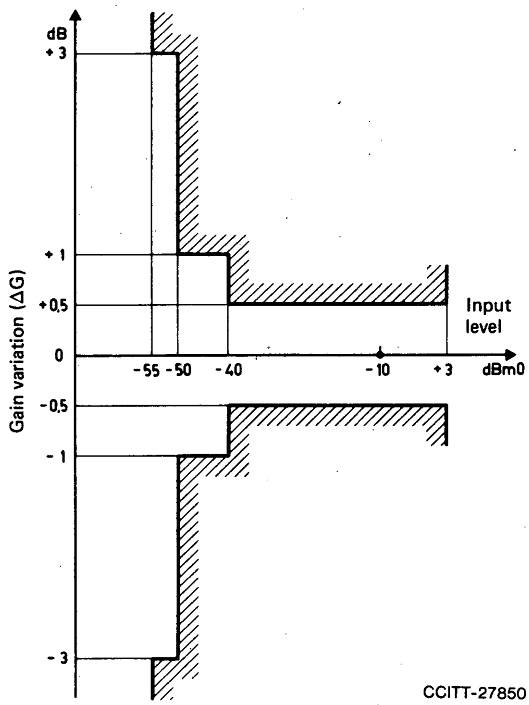
Note — The specification for the long-term stability is of a provisional nature.



a) Method 1: White noise test signal



b) Method 1: Sinusoidal test signal



c) Method 2: Sinusoidal test signal

FIGURE 6/G.712

Variation of gain (ΔG) with input level

16 Adjustment of the relationship between encoding law and audio level

The gain accuracy of the send and receive sides of PCM channels should each be within limits of ± 0.3 dB of the nominal value. Gain adjustments should be made as follows:

16.1 The receive side should be adjusted to conform with § 4 of Recommendation G.711 within a tolerance of ± 0.3 dB in practice.

16.2 The send side should be adjusted by connecting its output to the input of a receive side which has been adjusted to have precisely nominal gain, and applying a sine-wave signal of 1 kHz ± 20 Hz (excluding the submultiple of 8 kHz) at a level of 0 dBm0 to the audio input of the send side. The send side should then be adjusted so that the resulting sine-wave signal at the audio output of the receive side is at a level of 0 dBm0. In practice the adjustment should be made with a tolerance of ± 0.3 dB.

Alternatively, a receive side with a known error, within the limits defined in § 16.1, may be used provided that account is taken of this known error in adjusting the send side.

16.3 The load capacity of the send side may be checked by applying a sine-wave signal at a frequency of 1 kHz ± 20 Hz (excluding the submultiple of 8 kHz) at its audio input. The level of this signal should be initially well below T_{max} and should then be slowly increased. The input level should be measured at which the first occurrence is observed of the character signal corresponding to the extreme quantizing interval for both positive and negative values. T_{max} is taken as being 0.3 dB greater than the measured input level.

This method allows T_{max} to be checked for both positive and negative amplitudes and the values thus obtained should be within ± 0.3 dB of the theoretical load capacity (i.e. +3.14 dBm0 for the A-law or +3.17 dBm0 for the μ-law). As an alternative, the occurrence of the largest pulse amplitude at the decoder output may be used as a means of identifying T_{max}.

ANNEX A

(to Recommendation G.712)

Method of derivation of the signal-to-total distortion ratio for the A-law

The signal-to-quantizing distortion ratio produced by PCM systems can be obtained analytically in a number of different ways. The method adopted here is a special case of a more general analysis which enables the calculated results to be compared directly with those obtained by practical measurements of the systems.

The compression characteristic of the system is assumed to be "ideal" – i.e. to meet precisely the theoretical segmented law, with the system a.c. zero coincident with the centre decision amplitude. The input signal is assumed to be symmetrical about a.c. zero, and to have a gaussian distribution of instantaneous amplitudes. For a given input, of variance σ_v^2, the total output variance may be determined as σ_u^2, and the variance of the signal content in the output, by linear regression, as $m^2 \sigma_v^2$ where m is the slope of the regression line of output on input.

The variance of the distortion components is then $\sigma_\varepsilon^2 = \sigma_u^2 - m^2 \sigma_v^2$, and the signal-to-quantizing distortion ratio in dB is:

$$10 \log_{10} \frac{m^2 \sigma_v^2}{\sigma_\epsilon^2}$$

References

[1] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, Figure 5/G.232.

[2] CCITT Recommendation *Specification for a quantizing distortion measuring apparatus using a pseudo-random noise stimulus*, Vol. IV, Fascicle IV.4, Rec. O.131.

[3] CCITT Recommendation *Assumptions for the calculation of noise on hypothetical reference circuits for telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 7.

[4] CCITT Recommendation *Conventional telephone signal*, Vol. III, Fascicle III.2, Rec. G.227.

[5] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 11.

7.2 General Recommendations on digital systems and paths

Recommendation G.721

HYPOTHETICAL REFERENCE DIGITAL PATHS

(Geneva, 1976; amended at Geneva, 1980)

General definitions

hypothetical reference digital path

F: conduit numérique fictif de référence

S: trayecto digital ficticio de referencia

This is a hypothetical digital path of defined length and with a specified number of terminal and intermediate equipments, this number being sufficient but not excessive.

It forms a basis for the study of certain characteristics of long-distance digital paths (errors, jitter for example).

The design objectives recommended by the CCITT for transmission equipments are commonly expressed in terms of a maximum tolerable level of impairment arising in a hypothetical reference digital path.

As far as possible a design objective so expressed takes into account all possible usages of the system, e.g., for telephony, telegraphy, data, etc.

hypothetical reference digital path at 64 kbit/s

F: conduit numérique fictif de référence à 64 kbit/s

S: trayecto digital ficticio de referencia a 64 kbit/s

This is a complete digital path (between 64-kbit/s interfaces) established on a hypothetical international digital system and having a specified length and a specified number of multiplexing and demultiplexing equipments, these numbers being reasonably great but not having their maximum possible values.

Various "hypothetical reference digital paths" have been defined to allow the coordination of the different specifications concerning the constituent parts of the digital systems so that the complete connections set up on these systems can meet CCITT standards.

The CCITT has defined the following hypothetical reference digital paths:

- 2-Mbit/s system (see Figure 1/G.721),
- 8-Mbit/s system (see Figure 2/G.721),
- 34-Mbit/s system (see Figure 3/G.721),
- 140-Mbit/s system (see Figure 4/G.721),
- low bit rate systems based on G.733 hierarchy (see Figure 5/G.721),
- higher bit rate systems based on G.733 hierarchy (see Figure 6/G.721),
- very long digital paths on higher bit rate systems based on G.733 hierarchy (see Figure 7/G.721).

(Other hypothetical reference digital paths are under study.)

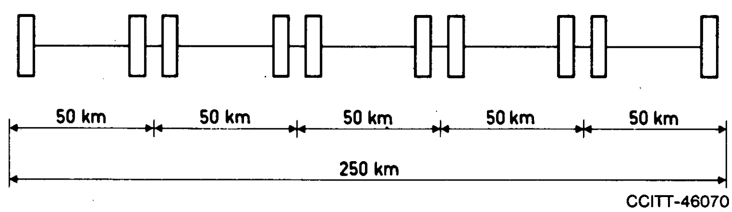


FIGURE 1/G.721

Hypothetical reference digital path for 2-Mbit/s systems

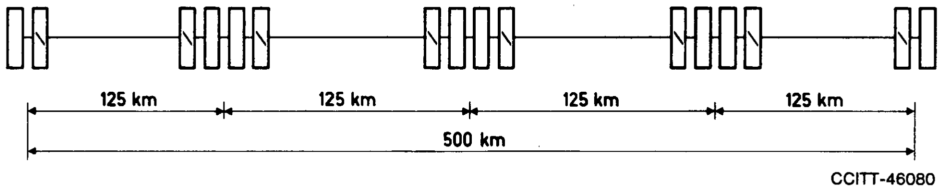


FIGURE 2/G.721

Hypothetical reference digital path for 8-Mbit/s systems

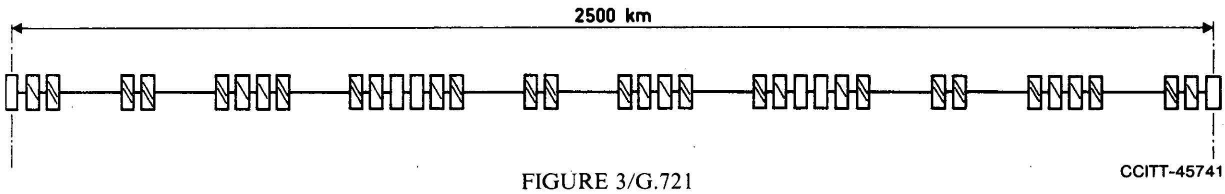


FIGURE 3/G.721

Hypothetical reference digital path for 34-Mbit/s systems, derived from the HRC for the 4-MHz system (Recommendation G.338 [1])

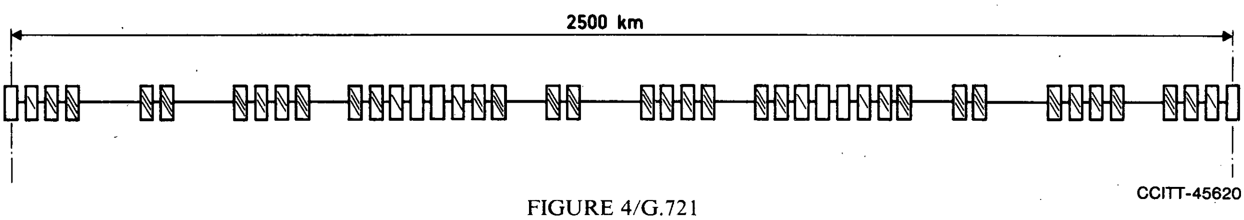
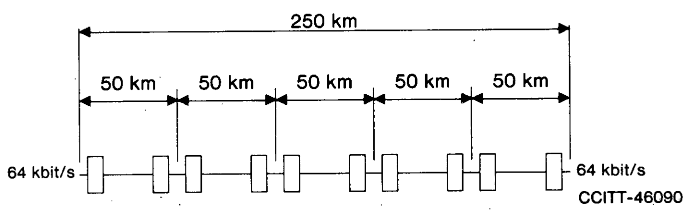


FIGURE 4/G.721

Hypothetical reference digital path for 140-Mbit/s systems



▯ Digital multiplex equipment necessary to achieve the proper bit rate. Each end of each homogeneous section will appear at a recommended hierarchical level. This legend is also valid for Figures 6/G.721 and 7/G.721.

FIGURE 5/G.721

Hypothetical reference digital path for digital sections normally operating at and below 6312 kbit/s and associated with 1544 kbit/s primary multiplex equipment

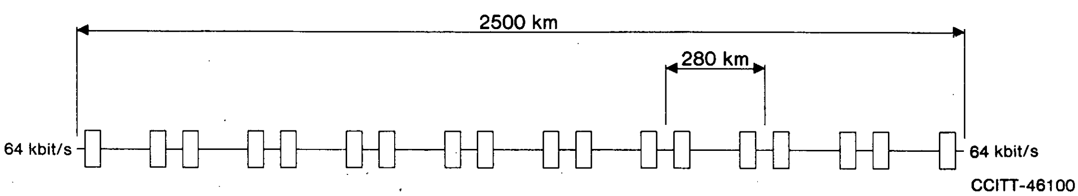


FIGURE 6/G.721

Hypothetical reference digital path for digital sections normally operating above 6312 kbit/s and associated with 1544 kbit/s primary multiplex equipment

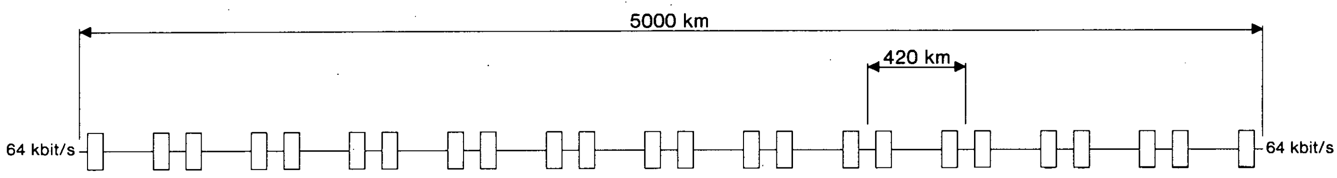


FIGURE 7/G.721

Hypothetical reference digital path for very long paths in digital sections normally operating above 6312 kbit/s and associated with 1544 kbit/s primary multiplex equipment

Each of these various hypothetical reference digital paths has a specified length and they are all used in the same way. They are a basis for the design of the transmission systems to which they relate, respectively, and of other transmission equipments which may be used in association with them.

In addition, because of the constitution of these hypothetical reference digital paths, they can be used not only to study the case of a path of the specified length, set up on a digital system or systems, but also that of an international connection having the same total length and made up of digital paths set up on different digital systems.

A homogeneous section is a section without diversion of multiplexing or demultiplexing of any one of the digital signals established on the system which is being considered, except for those multiplexing equipments defined at the ends of the section.

It is assumed that at the end of each homogeneous section, the digital paths, as appropriate, are connected through at random.

Reference

[1] CCITT Recommendation *4-MHz valve-type systems on standardized 2.6/9.5 mm coaxial cable pairs*, Orange Book, Vol. III-1, Rec. G.338, ITU, Geneva, 1977.

Recommendation G.722

INTERCONNECTION OF DIGITAL PATHS USING DIFFERENT TECHNIQUES

(Geneva, 1980)

The CCITT,

considering

(a) that some Administrations are continuing to design their networks on the basis of a transmission capability of 64-kbit/s bit sequence independent paths;

(b) that other Administrations are continuing to install 1544-kbit/s based equipment according to Recommendation G.733 with a minimum pulse density requirement;

(c) that digital line systems bearing the signals generated by CCITT recommended PCM multiplex equipment which are in existence throughout the world have slight differences. These differences arise from certain technical requirements for minimum pulse density. Because of the large number of line systems involved, it is not at this time economical to eliminate these requirements;

(d) and considering the need for interworking between networks and also considering the present and future services that can be provided, *the following actions are recommended*

(1) In circumstances where it is possible to do so without adversely affecting the operation and maintenance of existing digital transmission networks, newly designed digital transmission systems to be introduced should have a transmission capability which can provide bit sequence independence for 64-kbit/s paths.

(2) Where a specific limited demand can be identified for a 56- or 64-kbit/s bit sequence independent path for leased point-to-point customer service, special measures will be made by bilateral agreement to provide these services. However, CCITT recommended rates should normally be adhered to.

(3) Those concerned with the design and specifications of:

a) analogue to digital converters,

b) digital signalling systems,

c) digital multiplexers having inputs at rates lower than 64 kbit/s and outputs of *n* times 64 kbit/s (where *n* is an integer),

d) customer terminal equipment,

should take particular account of the pulse density requirement of 1544-kbit/s digital line systems which could be involved when such interworking occurs. The pulse density requirement has been variously stated but the appropriate text is reproduced below:

"For octet timed sources in 1544-kbit/s digital networks, it is required that at least one binary 1 should be contained in any octet of a 64-kbit/s digital signal. For a bit stream which is not octet timed, no more than seven consecutive 0s should appear in the 64 kbit/s signal."

7.3 Principal characteristics of primary multiplex equipment

Recommendation G.731

PRIMARY PCM MULTIPLEX EQUIPMENT FOR VOICE FREQUENCIES

(Geneva, 1972; amended at Geneva, 1980)

The CCITT,

considering

that pulse code modulation (PCM) multiplex equipments are already used in various countries, in particular to provide a large number of short-distance telephone circuits on certain pairs in existing cables, and in order to minimize the number of different PCM multiplex equipments providing circuits which may be used in international connections,

recommends

that Administrations concerned should make their choice between the two primary PCM multiplex equipments described in Recommendations G.732 and G.733.

CHARACTERISTICS OF PRIMARY PCM MULTIPLEX EQUIPMENT OPERATING AT 2048 kbit/s

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 General characteristics

1.1 *Fundamental characteristics*

The encoding law used in the A-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 256.

Note – The inversion of bits 2, 4, 6, and 8 is covered by the encoding law and is applicable only to voice-channel time slots.

1.2 *Bit rate*

The nominal bit rate is 2048 kbit/s. The tolerance on this rate is ± 50 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal of a PCM multiplex equipment from an internal source, from the incoming digital signal and also from an external source.

Note – Further study is required on the effect of jitter of the incoming signal on the timing signal, and on the measures to be taken in case of loss of the incoming signal or the external source.

2 Frame structure

2.1 *Number of bits per channel time slot*

Eight, numbered from 1 to 8.

2.2 *Number of channel time-slots per frame*

Thirty-two, numbered from 0 to 31. The number of bits per frame is 256, and the frame repetition rate is 8000 Hz.

2.3 *Channel time-slot assignment*

2.3.1 Channel time slots 1 to 15 and 17 to 31 are assigned to 30 telephone channels numbered from 1 to 30.

2.3.2 The allocation of the bits of channel time slot 0 is given in Table 1/G.732.

2.3.3 Channel time slot 16 is assigned to signalling as covered in § 4 below. If channel time slot 16 is not needed for signalling it may be used for purposes other than a voice channel encoded within the PCM multiplex equipment.

2.4 *Frame alignment signal*

The frame alignment signal occupies positions 2 to 8 in channel time-slot 0 of every other frame (see Table 1/G.732).

The frame alignment signal is:

0011011.

In order to avoid simulation of the frame alignment signal by bits 2 to 8 of channel time slot 0 in frames not containing the frame alignment signal, bit 2 in those channel time slots is fixed at 1.

TABLE 1/G.732

Allocation of bits in channel time slot 0

	Bit number							
	1	2	3	4	5	6	7	8
Time slot 0 containing the frame alignment signal	Reserved for international use (see Note 1)	0	0	1	1	0	1	1
		Frame alignment signal (see § 2.4)						
Time slot 0 not containing the frame alignment signal	Reserved for international use (see Note 1)	1 (see § 2.4)	Alarm indication to the remote PCM multiplex equipment (see § 3.2.3)	Reserved for national use (see Note 2)				

Note 1 – The use will be defined at a later stage. For the moment these bits are fixed at 1.
Note 2 – The bits allocated for national use may not be used internationally. On the digital path crossing the border, they are fixed at 1.

2.5 *Loss and recovery of frame alignment*

Frame alignment will be assumed to have been lost when three or four consecutive frame alignment signals have been received with an error.

Frame alignment will be assumed to have been recovered when the following sequence is detected:

– for the first time, the presence of the correct frame alignment signal;

– the absence of the frame alignment signal in the following frame detected by verifying that bit 2 in channel time-slot 0 is a 1;

– for the second time, the presence of the correct frame alignment signal in the next frame.

Note – To avoid the possibility of a state in which no frame alignment can be achieved due to the presence of an imitative frame alignment signal the following procedure may be used:

When a valid frame alignment signal is detected in frame n, a check should be made to ensure that a frame alignment signal does not exist in frame $n + 1$, and also that a frame alignment signal exists in frame $n + 2$. Failure to meet one or both of these requirements should cause a new search to be initiated in frame $n + 2$.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The PCM multiplex equipment should detect the following fault conditions:

3.1.1 Failure of power supply.

3.1.2 Failure of codec (except when using single-channel codecs).

As a minimum requirement this fault condition should be recognized when, for at least one signal level in the range −21 to −6 dBm0, the signal-to-quantizing noise ratio performance of the local codec is 18 dB or more below the level recommended in Recommendation G.712.

3.1.3 Loss of incoming signal at the 64-kbit/s input port (time slot 16).

Note 1 – The detection of this fault condition is not mandatory when channel associated signalling is used and the signalling multiplex is situated within a few metres of the PCM multiplex equipment.

Note 2 – The detection of this fault condition is not mandatory when contradirectional interfaces are used.

3.1.4 Loss of the incoming signal at 2048 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, the loss of either or both should constitute loss of the incoming signal.

3.1.5 Loss of frame alignment.

3.1.6 Excessive error ratio, detected in frame alignment signal.

3.1.6.1 Criteria for activating the indication of fault condition:

- Error ratio $\leq 1 \cdot 10^{-4}$

  The probability of activating the indication of fault condition in a few seconds should be less than 10^{-6}.

- Error ratio $\geq 1 \cdot 10^{-3}$

  The probability of activating the indication of fault condition in a few seconds should be higher than 0.95.

3.1.6.2 Criteria for deactivating the indication of fault condition:

- Error ratio $\geq 1 \cdot 10^{-3}$

  The probability for deactivating the indication of fault condition in a few seconds should be almost 0.

- Error ratio $\leq 1 \cdot 10^{-4}$

  The probability for deactivating the indication of fault condition in a few seconds should be higher than 0.95.

Note – The activating and the deactivating period specified as "a few seconds" is intended to be in the order of 4 to 5 seconds.

3.1.7 Alarm indication received from the remote PCM multiplex equipment (see § 3.2.3 below).

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.732. The consequent actions are as follows:

3.2.1 Service alarm indication generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded at least to the switching and/or signalling multiplex equipment depending upon the arrangements provided. The indication should be given as soon as possible and not later than 2 ms after detection of the relevant fault condition.

This specification, taking into account the specification given in § 2.5 above, is equivalent to recommending that the average time to detect a loss of frame alignment and to give the relevant indication should not be greater than 3 ms.

When using common-channel signalling, the indication should be forwarded to the switching equipment by means of a separate interface on the PCM multiplex equipment.

3.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see General Note below to § 3.2) is detected, the prompt maintenance alarm indication associated with loss of frame alignment (see § 3.1.5 above) and excessive error ratio (see § 3.1.6 above) should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.732 with the two fault conditions.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 3.2.1 and 3.2.2 above, is left to the discretion of each Administration.

3.2.3 Alarm indication to the remote end, transmitted by changing bit 3 of channel time-slot 0 from the state 0 to the state 1 in those frames not containing the frame alignment signal. This should be effected as soon as possible.

3.2.4 Transmission suppressed at the analogue outputs.

3.2.5 AIS applied to time-slot 16 64-kbit/s output (see General Note below to § 3.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

3.2.6 AIS applied to time slot 16 of the output 2048-kbit/s composite signal (if supervision of the incoming 64-kbit/s signal is provided).

General Note to § 3.2 – The equivalent binary content of the AIS is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that the AIS is detectable, even in the presence of an error ratio of $1 \cdot 10^{-3}$. However, a signal with all bits except the frame alignment in the 1 state, should not be mistaken as an AIS.

Remark – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

TABLE 2/G.732

Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	Fault conditions (see § 3.1)	Consequent actions (see § 3.2)					
		Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end transmitted	Transmission suppressed at the analogue outputs	AIS applied to 64 kbit/s output (time slot 16)	AIS applied to time slot 16 of the 2048 kbit/s composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes	Yes (if practicable)	Yes (if practicable)	Yes (if practicable)	Yes (if practicable)
	Failure of codec	Yes	Yes	Yes	Yes		
Multiplexer only	Loss of incoming signal at 64-kbit/s input time slot 16 (see Notes under § 3.1.3)		Yes				Yes
Demultiplexer only	Loss of incoming signal at 2048 kbit/s	Yes	Yes	Yes	Yes	Yes	
	Loss of frame alignment	Yes	Yes	Yes	Yes	Yes	
	Error ratio $1 \cdot 10^{-3}$ for the alignment signal	Yes	Yes	Yes	Yes	Yes	
	Alarm indication received from the remote end (bit 3 of time slot 0)	Yes					

Note – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

4 Signalling

The use of channel time slot 16 is recommended for either common channel or channel associated signalling as required. The actions described in § 3.2.1 above, consequent to the corresponding fault conditions according to Table 2/G.732 should be applied.

Channel time slot 16 may be used to provide an interface at 64 kbit/s which shall be suitable for use with either common channel or channel associated signalling. The action described in § 3.2.5 above, consequent to the corresponding fault conditions according to Table 2/G.732 should be applied.

The detailed requirements for the organization of particular signalling systems will be included in the specifications for those signalling systems.

4.1 *Common channel signalling*

Channel time slot 16 may be used for common channel signalling up to a rate of 64 kbit/s. The method of obtaining signal alignment will form part of the particular common channel signalling specification. In this case the 64-kbit/s interface to be used for time slot 16 should be in accordance with § 5 below and Recomenda-tion G.703.

4.2 *Channel associated signalling*

This paragraph contains the recommended arrangement for use of the 64-kbit/s capability of channel time slot 16 for channel associated signalling.

4.2.1 *Multiframe structure*

A multiframe comprises 16 consecutive frames (whose structure is given in § 2.2 above) and these are numbered from 0 to 15.

The multiframe alignment signal is 0000 and occupies digit time slots 1 to 4 of channel time slot 16 in frame 0.

4.2.2 *Allocation of channel time slot 16*

When channel time slot 16 is used for channel associated signalling it provides a 64-kbit/s digital path which is subdivided into lower-rate paths using the multiframe alignment signal as a reference.

Details of the bit allocation are given in Table 3/G.732.

TABLE 3/G.732

Channel time slot 16 of frame 0	Channel time slot 16 of frame 1		Channel time slot 16 of frame 2		Channel time slot 16 of frame 15	
0000 *xyxx*	*abcd* channel 1	*abcd* channel 16	*abcd* channel 2	*abcd* channel 17	*abcd* channel 15	*abcd* channel 30

Note – *x* = spare bit to be made 1 if not used.
y = bit used to indicate loss of multiframe alignment (see § 4.2.4.2.3 below).
When bits *b*, *c* or *d* are not used they should have the value :
b = 1
c = 0
d = 1
It is recommended that the combination 0000 of bits *a*, *b*, *c* and *d* should not be used for signalling purposes for channels 1-15.

This bit allocation provides four 500-bit/s signalling channels designated *a*, *b*, *c* and *d*, for each telephone channel. With this arrangement, the signalling distortion of each signalling channel introduced by the PCM transmission system, will not exceed ± 2 ms.

4.2.3 *Loss and recovery of multiframe alignment*

Multiframe alignment should be assumed to have been lost when two consecutive multiframe alignment signals have been received with an error.

Multiframe alignment should be assumed to have been recovered as soon as the first correct multiframe alignment signal is detected.

Note – To avoid a condition of spurious multiframe alignment, the following procedure may be used in addition to the above:

- Multiframe alignment should be assumed to have been lost when, for a period of one or two multiframes, all the bits in time slot 16 are in state 0.
- Multiframe alignment should be assumed to have been recovered only when at least one bit in state 1 is present in the time slot 16 preceding the multiframe alignment signal first detected.

4.2.4 *Fault conditions and consequent actions*

4.2.4.1 *Fault conditions*

The signalling multiplex equipment should detect the following fault conditions:

4.2.4.1.1 Failure of power supply.

4.2.4.1.2 Loss of 64-kbit/s incoming signal at the input of the signalling demultiplexer.

Note 1 – The detection of this fault condition is not mandatory when the signalling multiplex equipment is situated within a few metres of the PCM multiplex equipment or when this fault condition results in an indication of loss of multiframe alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

4.2.4.1.3 Loss of multiframe alignment.

4.2.4.1.4 Alarm indication received from the remote signalling multiplex equipment (see § 4.2.4.2.3 below).

4.2.4.1.5 Receipt of the service alarm indication from the PCM multiplex equipment (see § 3.2.1 above).

4.2.4.2 *Consequent actions*

Further to the detection of a fault condition appropriate actions should be taken as specified in Table 4/G.732. The consequent actions are as follows:

4.2.4.2.1 Service alarm indication to be forwarded to the switching equipment depending upon the switching and signalling arrangements provided.

4.2.4.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenace attention is required locally. If provision is made for detecting the AIS, then on the reception of the AIS, the prompt maintenance alarm indication should be inhibited in the case of loss of multiframe (see § 4.2.4.1.3 above).

Note – The location and provision of any visual and or audible alarms activated by the alarm indications given in §§ 4.2.4.2.1 and 4.2.4.2.2 above is left to the discretion of each Administration.

4.2.4.2.3 Alarm indication to the remote signalling multiplex equipment, generated by changing from the state 0 to the state 1 bit 6 of channel time slot 16 of frame 0 of the multiframe (see Table 3/G.732); this should be effected as soon as possible.

4.2.4.2.4 Application of the condition corresponding to state 1 on the line to all receive signalling channels. This condition should be forwarded as soon as possible and not later than 3 ms after the detection of the fault condition.

Note – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

TABLE 4/G.732

Fault conditions and consequent actions for channel-associated signalling multiplex equipment

Equipment part	Fault conditions (see § 4.2.4.1)	Consequent actions (see § 4.2.4.2)			
		Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end transmitted	Application of state, equivalent to state 1, on line to all receive signalling channels
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes	Yes (if practicable)	Yes (if practicable)
Demultiplexer only	Loss of incoming signal	Yes	Yes	Yes	Yes
	Loss of multiframe alignment	Yes	Yes	Yes	Yes
	Alarm indication received from the remote signalling multiplex equipment	Yes			Yes
	Receipt of the service alarm indication from PCM mux	Yes			Yes

Note – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

5 Interfaces

The analogue interfaces should be in accordance with Recommendation G.712.

The digital interfaces should be in accordance with Recommendation G.703.

The specifications for 64-kbit/s interfaces are not mandatory for channel associated signalling.

6 Jitter

6.1 *Jitter at 2048-kbit/s output*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 2048-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 100 kHz.

6.2 *Jitter at 64-kbit/s output*

Under study.

CHARACTERISTICS OF PRIMARY PCM MULTIPLEX EQUIPMENT OPERATING AT 1544 kbit/s

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 General characteristics

1.1 *Fundamental characteristics*

The encoding law used is the μ-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 255. Two character signals are reserved for zero value (11111111 and 01111111).

In some networks the all 0 character signal (00000000) is eliminated to avoid loss of timing information to the digital line, resulting in 254 quantized values.

1.2 *Bit rate*

The nominal bit rate is 1544 kbit/s. The tolerance on this rate is ± 50 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal of a PCM multiplex equipment from an internal source, from the incoming digital signal and also from an external source.

2 Frame structure

2.1 *Number of bits per channel time slot:* eight, numbered 1 to 8.

2.2 *Number of channel time slots per frame:* twenty-four, numbered from 1 to 24.

One bit frame is added for a frame alignment signal and for a multiframe alignment signal or signalling.

The number of bits per frame is 193, and the frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment*

2.3.1 Channel time slots 1 to 24 are assigned to 24 telephone channels numbered 1 to 24.

2.3.2 Allocation of the frame alignment signal and *S*-bit (for multiframe alignment or signalling) is given in Table 1/G.733.

TABLE 1/G.733

Frame number	Frame alignment signal (see § 2.4)	Multiframe alignment signal or signalling
1	1	–
2	–	*S*
3	0	–
4	–	*S*

2.3.3 The assignment of the *S*-bit is covered in § 4 below.

2.4 *Frame alignment signal*

The frame alignment signal occupies the first bit position of every other frame.

This signal is: 101010 . . .

2.5 *Loss and recovery of frame alignment*

The frame alignment signal should be monitored to determine if frame alignment has been lost. Frame alignment should be recovered after a valid frame alignment signal is available at the receiving terminal equipment.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The PCM multiplex equipment should detect the following conditions:

3.1.1 Failure of power supply.

3.1.2 Loss of incoming signals at 1544 kbit/s.

3.1.3 Loss of frame alignment.

3.1.4 Alarm indication received from the remote PCM multiplex equipment.

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.733. The consequent actions are as follows:

3.2.1 A service alarm indication should be generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded to the switching and/or signalling equipment depending upon the arrangement provided.

3.2.2 The service alarm described in § 3.2.1 above should be used to automatically remove the associated circuits from service and to restore them to service when frame alignment has been recovered.

Note – The removal of the associated circuits described in § 3.2.2 above should be done in such a way that the circuits are not needlessly removed in the case of a brief isolated loss of frame alignment but are removed in the case of a permanent or intermittent loss of frame alignment.

It is also important to minimize the impact of signalling errors which may occur during periods of loss of frame alignment. These functions should be provided in the PCM multiplex equipment or in the switching/signalling equipment.

3.2.3 A prompt maintenance alarm indication should be generated to signify that performance is below acceptable standards and maintenance attention is required locally.

3.2.4 An alarm indication to the remote end should be generated by either forcing bit 2 in every channel time slot to the value 0 or by modifying the *S*-bit as described in § 4.2.1 below.

3.2.5 Transmission should be suppressed at the analogue outputs.

3.2.6 *Rapid indication of loss of frame alignment*

An indication should be given to the Signalling System No. 6 equipment (digital version) when the PCM multiplex equipment (local end only) detects a loss of frame alignment. The average time to detect and give an indication of random bits in the frame alignment signal bit positions should not be greater than 3 ms. This indication will serve the same function as that provided by the data carrier failure alarm in the analogue version (see Recommendation Q.275 [1]).

TABLE 2/G.733

Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	Fault conditions	Consequent actions			
		Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end generated	Transmission suppressed at the analogue outputs
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes	Yes (if practicable)	Optional
Demultiplexer only	Loss of incoming signals at 1544 kbit/s	Yes	Yes	Yes	Yes
	Loss of frame alignment	Yes	Yes	Yes	Yes
	Alarm indication received from the remote end	Optional	Yes		Optional

Note 1 – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action

Note 2 – Indications of additional fault conditions, such as codec failure and excessive bit errors, are left to the discretion of individual Administrations.

4 Signalling

4.1 *Common channel signalling*

The pattern of the *S*-bit may be arranged to carry common channel signalling at a rate of 4 kbit/s or a submultiple of this rate.

4.2 *Channel associated signalling*

Based on agreement between the Administrations involved, channel associated signalling is provided for intraregional circuits according to the following arrangement:

4.2.1 *Multiframe structure*

A multiframe comprises 12 frames as shown in Table 3/G.733. The multiframe alignment signal is carried on the *S*-bit, as shown in the table.

TABLE 3/G.733

Multiframe structure

Frame number	Frame alignment signal (see Note 1)	Multiframe alignment signal (*S* bit)	Bit number(s) in each channel time slot		Signalling channel designation (see Note 2)
			For character signal	For signalling	
1	1	–	1 - 8	–	
2	–	0	1 - 8	–	
3	0	–	1 - 8	–	
4	–	0	1 - 8	–	
5	1	–	1 - 8	–	
6	–	1	1 - 7	8	A
7	0	–	1 - 8	–	
8	–	1	1 - 8	–	
9	1	–	1 - 8	–	
10	–	1	1 - 8	–	
11	0	–	1 - 8	–	
12	–	0	1 - 7	8	B

Note 1 – When the *S*-bit is modified to signal the alarm indications to the remote end as indicated in § 3.2.4, the *S*-bit in frame 12 is changed from 0 to 1.

Note 2 – Channel associated signalling provides two independent 667-bit/s signalling channels designated A and B or one 1333-bit/s signalling channel.

4.2.2 *Loss of multiframe alignment*

Loss of multiframe alignment is assumed to have taken place when loss of frame alignment occurs.

4.2.3 *Allocation of signalling bits*

Frames 6 and 12 are designated as signalling frames. The eighth bit in each channel time slot is used in every signalling frame to carry the signalling associated with that channel.

4.2.4 *Minimization of quantizing distortion*

In the signalling frame only seven bits are available for encoding of voice frequencies. In order to minimize the quantizing distortion, the decoder output values are shifted slightly. All even numbered decoder output values y_n, are changed to be equal to the next higher decision value, i.e. x_{n+1}. All odd numbered decoder output values y_{n+1} are changed to be equal to the same numbered decision value, i.e. x_{n+1}, as shown on Figure 1/G.733.

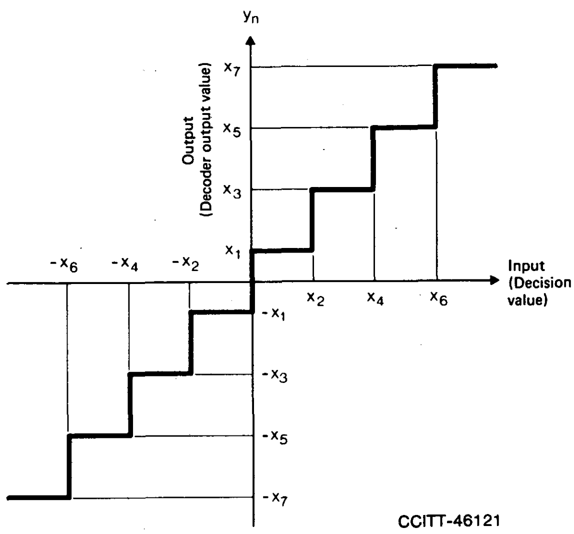


FIGURE 1/G.733

Seven-bit codec transfer characteristic

When suppression of the all 0 character signal is required, the value of the seventh bit is forced to be 1 when all the other bits of the character signal have the value 0.

5 Interfaces

Analogue: See Recommendation G.712.

Digital: See Recommendation G.703.

Reference

[1] CCITT Recommendation *Data channel failure detection*, Vol. VI, Fascicle VI.3, Rec. Q.275.

Recommendation G.734

CHARACTERISTICS OF 2048-kbit/s FRAME STRUCTURE FOR USE WITH DIGITAL EXCHANGES

(Geneva, 1976)

1 General characteristics

The multiplex structure described in this Recommendation is suitable for use on 2048-kbit/s digital paths which terminate at digital exchanges. The structure is compatible with that of the PCM primary multiplex described in Recommendation G.732, and is applicable to digital paths which connect such PCM multiplex equipments to exchanges and to digital paths which interconnect digital exchanges.

Some of the characteristics of this multiplex structure are identical to those in Recommendation G.732 and are covered by cross references to that Recommendation.

1.1 *Fundamental characteristics*

The multiplex structure contains 32 time slots, each of 64 kbit/s, which are all switchable. In time slots allocated to telephony, speech will be encoded according to Recommendation G.711. Time slots allocated to other services may need to be utilized in an agreed manner (e.g. Recommendation X.50 [1] for synchronous data services).

1.2 *Bit rate*

The nominal bit rate is 2048 kbit/s. This rate will be controlled to within at least ± 50 parts per million (ppm) at the transmitting end for each direction of transmission.

1.3 *Timing signal*

The timing signal is a 2048-kHz signal from which the bit rate is derived.

1.3.1 *Timing in a nonsynchronized network*

For a PCM multiplex equipment, the timing signal will be derived from the incoming timing signal at the receive side. For a digital exchange, the transmitting timing signal will be derived from a clock within the digital exchange.

1.3.2 *Timing in a synchronized network*

In case of synchronous operation of the network, a network synchronization system will maintain the timing signal or clocks within agreed timing limits.

1.4 *Interfaces*

Refer to § 5 of Recommendation G.732 and Recommendation G.703. No interface, internal to the switch, will be recommended.

1.5 *Transmission performance*

The transmission performance of the digital path will be the same as that for 2048-kbit/s digital paths between primary PCM multiplex equipments.

2 **Frame structure**

The frame structure, frame alignment procedures, and normally the time-slot assignment will be as defined in Recommendation G.732.

Where more signalling capacity is required between exchanges, additional time slots may be utilized for common channel signalling. They should be selected from the slots allocated in PCM multiplexes for data purposes. On routes between exchanges comprising more than one 2048-kbit/s digital path, it may be possible to provide an adequate signalling capacity without using time slot 16 of all systems on the route. In these circumstances time slot 16 in those systems not carrying signalling can be allocated to speech or other services. Time slot 0 is reserved for frame alignment, alarms and network synchronization information and should not be used for signalling or speech purposes.

3 **Fault conditions and consequent actions**

3.1 *Fault conditions*

The PCM multiplex equipment should detect the fault conditions mentioned in Recommendation G.732, § 3.1.

The digital exchange terminal equipment should detect the following fault conditions.

3.1.1 Failure of power supply.

3.1.2 Loss of the incoming signal at 2048 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

3.1.3 Loss of frame alignment.

3.1.4 Excessive error rate detected in the frame alignment signal. The criteria for activating and deactivating the indication of this fault condition are given in Recommendation G.732, § 3.1.6.

3.1.5 Alarm indication received from the remote end (see § 3.2.3 below).

3.2 *Consequent actions*

Further to the detection of a fault condition, for PCM multiplexing equipment appropriate actions should be taken as specified by Table 2/G.732 and Recommendation G.732, § 3.2.

The consequent actions for the digital exchange are specified by Table 1/G.734 and are as follows:

3.2.1 Service alarm indication generated to signify that the service provided by the exchange terminal (ET) is no longer available. This indication should be given by the ET as soon as possible and not later than 2 ms after the detection of the relevant fault condition.

This specification, taking into account the specification given in Recommendation G.732, § 2.5 is equivalent to recommending that the average time to detect a loss of frame alignment and to give the relevant indication should not be greater than 3 ms.

3.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 1 below) is detected, the prompt maintenance alarm indication, associated with loss of frame alignment and excessive error rate in the frame alignment pattern, should be inhibited.

3.2.3 Alarm indication to the remote end generated by changing bit 3 of channel time slot 0 from the state 0 to the state 1 in those frames not containing the frame alignment signal. This should be effected as soon as possible.

3.2.4 Alarm Indication Signal (see Note 1 below) applied in all received time slots containing speech, data and/or signalling. This action should be taken as soon as possible and not later than 2 ms after detection of the fault conditions mentioned in §§ 3.1.1, 3.1.2, 3.1.3 and 3.1.4 above.

TABLE 1/G.734

Fault conditions and consequent actions for the digital exchange

Fault conditions (see § 3.1)	Consequent actions (see § 3.2)			
	Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end generated	AIS applied in the exchange terminal
Failure of power supply	Yes	Yes	Yes (if practicable)	Yes (if practicable)
Loss of incoming signal at 2048 kbit/s	Yes	Yes	Yes	Yes
Loss of frame alignment	Yes	Yes	Yes	Yes
Error rate 1 in 10^{-3} for the alignment signal	Yes	Yes	Yes	Yes
Alarm indication received from the remote end	Yes			

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Note 1 – The equivalent binary content of the AIS is a continuous stream of 1s.

Note 2 – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

Note 3 – The utilization of these indications will depend upon the switching and signalling arrangements provided nationally. Separate indications for some of the fault conditions listed may be provided nationally if required.

The reaction of the processing equipment on the fault indication and the times within which the service and maintenance alarms should be provided need further study.

Reference

[1] CCITT Recommendation *Fundamental parameters of a multiplexing scheme for the international interface between synchronous data networks*, Vol. VIII, Fascicle VIII.3, Rec. X.50.

Recommendation G.735

CHARACTERISTICS REQUIRED TO TERMINATE 1544-kbit/s DIGITAL PATHS ON A DIGITAL EXCHANGE

(Geneva, 1980)

1 General characteristics

This Recommendation defines interface conditions and fundamental functions of digital exchange terminal equipment used to terminate 1544-kbit/s paths. The multiplex structure is compatible with that of the PCM multiplex equipment described in Recommendation G.733, and is applicable to digital paths which connect such PCM multiplex equipments to exchanges and to digital paths which interconnect digital exchanges.

1.1 *Fundamental characteristics*

The multiplex structure contains 24 time slots, each of 64 kbit/s, which are all switchable. In time slots allocated to telephony, speech will be encoded according to Recommendation G.711. Time slots allocated to other services may need to be utilized in an agreed manner (e.g. Recommendation X.50 [1] for synchronous data services).

1.2 *Bit rate*

The nominal bit rate is 1544 kbit/s.

Note – The tolerance on this bit rate should be further studied and specified.

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal from an external source as specified below.

Note – For PCM multiplex equipment at the remote end, the timing signal will be derived from the incoming signal at the receive end.

1.3.1 *Timing in a non synchronized network*

For a digital exchange the transmitting timing signal will be derived from an office clock.

1.3.2 *Timing in a synchronized network*

In case of synchronous operation of the network, a network synchronization system will maintain the signal or clocks within agreed timing limits.

1.4 *Interfaces*

Refer to § 1 of Recommendation G.703. No interface internal to the switch will be recommended.

1.5 *Transmission performance*

Transmission performance of the digital path should be the same as that for 1544-kbit/s digital paths between primary PCM multiplex equipment.

2 Frame structure

The frame structure and time slot assignments should be as defined in § 2 of Recommendation G.733.

3 Synchronization performances

The digital exchange terminal is a synchronous digital terminal which has a frame aligner circuit. Therefore, such synchronization performances as specified below should be defined.

3.1 *Wander at the input*

Maximum wander at the input is under study.

3.2 *Jitter at the input*

Jitter at the input is under study.

3.3 *Jitter at the output*

Jitter at the output is under study.

3.4 *Slips*

The slip rate should conform with the requirements specified in Recommendation G.822.

3.5 *Forms of frame aligner*

The frame aligner should be able to compensate a maximum wander without introducing slips, and slips should not bring about loss of frame alignment.

4 Compatibility with other terminals

Since the 1544-kbit/s path may be connected at the remote end to a PCM multiplex designed according to Recommendation G.733, the exchange terminal should respond to fault conditions in a manner compatible with the actions specified in §§ 3.2.1 and 3.2.2 of Recommendation G.733.

Reference

[1] CCITT Recommendation *Fundamental parameters of a multiplexing scheme for the international interface between synchronous data networks*, Vol. VIII, Fascicle VIII.3, Rec. X.50.

Recommendation G.736

CHARACTERISTICS OF SYNCHRONOUS DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 1544 kbit/s

(Geneva, 1980)

1 General characteristics

This Recommendation defines the characteristics of a synchronous multiplex equipment currently used for applications in dedicated data networks, to combine up to 23 tributary channels at 64 kbit/s in a 1544-kbit/s digital stream.

Note – For applications within an ISDN, it is expected that a 24-channel multiplex will be used that has a frame structure conforming to Recommendation G.733.

1.1 *Bit rate*

The nominal bit rate is 1544 kbit/s.

Note – The tolerance on this rate should be studied and specified.

1.2 *Timing signals*

It should be possible to derive the multiplexer timing signals from the composite clock signal of a centralized clock source as specified in Recommendation G.703, and from the 1544-kbit/s incoming digital stream.

Note – The desirability of also providing a 1544-kHz transmitting timing signal from a centralized clock source should be further studied.

2 Frame structure

2.1 *Number of bits per channel time slot*

There are eight bits per channel time slot, numbered from one to eight.

2.2 *Number of channel time slots per frame*

There are 24 time slots per frame, numbered from 1 to 24. Successive bits for bytes 1 to 24 should be consecutively numbered from 2 to 193. The first bit should be reserved for optional use. The frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment*

2.3.1 Channel time slots 1 to 23 are assigned to tributaries.

2.3.2 Channel time slot 24 is assigned to frame alignment and service digits. Two alternative methods, as given in Tables 1/G.736 and 2/G.736 for allocation of these signals and associated frame alignment strategy are recommended.

TABLE 1/G.736

Allocation of time slot 24, Method 1

Bit number of time slot 24							
1	2	3	4	5	6	7	8
					Service digits		
Frame alignment signal							
1	0	1	1	1			0

Note – Loss of frame alignment should be assumed to have taken place when more than three of twelve successive frames have an error in the frame alignment signal and/or in bit 1 of the 193-bit frame. Frame alignment should be assumed to have been recovered when four consecutive correct frame alignment signals have been received.

TABLE 2/G.736

Allocation of time slot 24, Method 2

Frame number	Bit number of time slot 24							
	1	2	3	4	5	6	7	8
1	Service digits			Frame alignment signal 0	0	1	0	1
2				1	1	0	1	0

Note – Loss of frame alignment should be assumed to have taken place when seven consecutive pairs of the frame alignment signal (00101, 11010) have been incorrectly received in their predicted positions. Frame alignment should be assumed to have been recovered when two consecutive correct pairs of frame alignment signals have been received.

2.4 *Service digits*

The use of service digits in channel time slot 24 is under study.

Note – The first bit could be considered for framing algorithms.

3 Fault conditions and consequent action

3.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

- failure of power supply,
- loss of the incoming signal at 1544 kbit/s,
- loss of frame alignment,
- loss of timing signals supplied from the centralized clock,
- alarm indication received from the remote digital multiplex equipment.

Some of the above fault conditions may optionally be detected by auxiliary equipment normally used in association with the digital multiplex equipment.

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 3/G.736.

4 Multiplexing method

Cyclic byte interleaving in the tributary numbering order should be used. The digital multiplex equipment should translate any incoming byte that contains only 0s into the zero byte suppression code.

Note 1 – The content of the zero byte suppression code is under study.

Note 2 – Further study is needed for the case when the zero suppression code must be extracted.

TABLE 3/G.736

Fault conditions and consequent actions for the digital multiplex equipment

Equipment part	Fault conditions	Consequent action (see Notes 1 and 2)		
		Prompt maintenance alarm indication generated	Alarm indication to the remote transmitted (see Note 3)	Multiplex out-of-sync signal applied to 64 kbit/s output (see Note 4)
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes (if practicable)	Yes (if practicable)
Demultiplexer only	Loss of incoming signal at 1544 kbit/s	Yes	Yes	Yes
	Loss of frame alignment	Yes	Yes	Yes
	Alarm indication receive from the remote end	Yes		

Note 1 – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present, the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Note 2 – These consequent actions may optionally be taken by auxiliary equipment normally used in conjunction with the digital multiplex equipment.

Note 3 – The alarm indication to the remote end may be generated by changing a service bit of time slot 24 from the state 1 to the state 0, if possible.

Note 4 – The binary content of the multiplex out-of-sync signal is under study. One Administration uses 00011010.

5 Input jitter and wander

The amount of jitter and wander that should be accepted at the input of the demultiplexer should be studied and specified.

When the input buffer overflows (underflows), one controlled slip (repetition) should be induced.

6 Digital interface

The digital interface at 64 kbit/s and 1544 kbit/s should be in accordance with Recommendation G.703.

CHARACTERISTICS OF PRIMARY PCM MULTIPLEX EQUIPMENT OPERATING AT 2048 kbit/s AND OFFERING SYNCHRONOUS 64-kbit/s DIGITAL ACCESS OPTIONS

(Geneva, 1980)

This Recommendation gives the characteristics of a PCM multiplex equipment operating at 2048 kbit/s and offering synchronous 64-kbit/s internal digital access options. It is foreseen that in the future the need may arise to devote $n \times 64$ kbit/s time slots to services requiring more than a single 64-kbit/s channel. The additions to this Recommendation to allow this facility (e.g. definition of proper interfaces at $n \times 64$ kbit/s) are under study.

1 General characteristics

1.1 *Fundamental characteristics for voice channel encoding*

The encoding law used is the A-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 256.

Note – The inversion of bits 2, 4, 6 and 8 is covered by the encoding law and is applicable only to voice channel time slots.

1.2 *Bit rate*

The nominal bit rate is 2048 kbit/s. The tolerance on this rate is ± 50 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmit timing signal from any of the following:

a) from the received 2048 kbit/s signal,

b) from an external source at 2048 kHz (see § 5),

c) from an internal oscillator.

Note – The provision of a timing signal output, available for the purpose of synchronizing other equipments, is an option that might be required depending upon national synchronization arrangements.

2 Frame structure

2.1 *Number of bits per channel time slot*

Eight, numbered from 1 to 8.

2.2 *Number of channel time slots per frame*

Thirty-two, numbered from 0 to 31. The number of bits per frame is 256, and the frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment*

2.3.1 It should be possible to assign channel time slots 1 to 15 and 17 to 31 to thirty telephone channels numbered from 1 to 30.

Provision should also be made to provide 64-kbit/s digital access to at least 2 of these channel time slots. These channel time slots should be allocated in the following order of priority: 6 – 22 – 14 – 30 – 2 – 18 – 10 – 26 – 4 – 20 – 12 – 28 – 8 – 24 – 5 – 21 – 13 – 29 – 1 – 17 – 9 – 25 – 3 – 19 – 11 – 27 – 7 – 23 – 15 – 31.

2.3.2 The allocation of the bits of channel time slot 0 is given in Table 1/G.737:

TABLE 1/G.737

Allocation of bits in channel time slot 0

	Bit number							
	1	2	3	4	5	6	7	8
Time slot 0 containing the frame alignment signal	Reserved for international use (see Note 1)	0	0	1	1	0	1	1
		Frame alignment signal (see § 2.4)						
Time slot 0 not containing the frame alignment signal	Reserved for international use (see Note 1)	1 (see § 2.4)	Alarm indication to the remote PCM multiplex equipment (see § 3.2.3)	Reserved for national use (see Note 2)				

Note 1 – The use will be defined at a later stage. For the moment, these bits are fixed at 1.

Note 2 – The bits allocated for national use may not be used internationally. On the digital path crossing the border, they are fixed at 1.

2.3.3 Channel time slot 16 is assigned to signalling as covered in § 4. If channel time slot 16 is not needed for signalling, it may be used for purposes other than a voice channel encoded within the PCM multiplex equipment.

2.4 *Frame alignment signal*

The frame alignment signal occupies positions 2 to 8 in channel time slot 0 of every other frame (see Table 1/G.737).

The frame alignment signal is: 0011011.

In order to avoid simulation of the frame alignment signal by bits 2 to 8 of channel time slot 0 in frames not containing the frame alignment signal, bit 2 in those channel time slots is fixed at 1.

2.5 *Loss and recovery of frame alignment*

Frame alignment will be assumed to have been lost when three or four consecutive frame alignment signals have been received with an error.

Note 1 – In addition to the preceding, in order to limit the effect of imitative frame alignment signals, the following procedure may be used:

Frame alignment will also be assumed to have been lost when bit 2 in time slot 0 in frames not containing the frame alignment signal has been received with an error on three or four consecutive occasions.

Frame alignment will be assumed to have been recovered when the following sequence is detected:

- for the first time, the presence of the correct frame alignment signal;
- the absence of the frame alignment signal in the following frame detected by verifying that bit 2 in channel time slot 0 is a 1;
- for the second time, the presence of the correct frame alignment signal in the next frame.

Note 2 – To avoid the possibility of a state in which no frame alignment can be achieved due to the presence of an imitative frame alignment signal, the following procedure may be used:

When a valid frame alignment signal is detected in frame n, a check should be made to ensure that a frame alignment signal does not exist in frame $n + 1$, and also that a frame alignment signal exists in frame $n + 2$. Failure to meet one or both of these requirements should cause a new search to be initiated in frame $n + 2$.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The PCM multiplex equipment should detect the following fault conditions:

3.1.1 Failure of power supply.

3.1.2 Failure of codec (except when using single channel codecs).

As a minimum requirement, this fault condition should be recognized when for at least one signal level in the range −21 to −6 dBm0, the signal-to-quantizing noise ratio performance of the local codec is 18 dB or more below the level recommended in Recommendation G.712.

3.1.3 Loss of incoming signals at the 64-kbit/s tributary input port.

Note 1 – This detection is not mandatory when contradirectional interfaces are used.

Note 2 – The detection of this fault condition is not mandatory for channel time slot 16 when channel associated signalling is used and the signalling multiplex equipment is situated within a few metres of the PCM multiplex equipment.

3.1.4 Loss of the incoming signal at 2048 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, the loss of either or both should constitute loss of the incoming signal.

3.1.5 Loss of frame alignment.

3.1.6 Error ratio, detected in frame alignment signal, exceeding 1 in 10^{-3}.

3.1.6.1 Criteria for activating the indication of fault condition:

- error ratio $\leqslant 1 \cdot 10^{-4}$: the probability of activating the indication of fault condition in a few seconds should be less than 10^{-6};
- error ratio $\geqslant 1 \cdot 10^{-3}$: the probability of activating the indication of fault condition in a few seconds should be higher than 0.95.

3.1.6.2 Criteria for deactivating the indication of fault condition:

- error ratio $\geqslant 1 \cdot 10^{-4}$: the probability for deactivating the indication of fault condition in a few seconds should be almost 0;
- error ratio $\leqslant 1 \cdot 10^{-3}$: the probability for deactivating the indication of fault condition in a few seconds should be higher than 0.95.

Note – The activating and the deactivating period specified as "a few seconds" is intended to be in the order of 4 to 5 seconds.

3.1.7 Alarm indication received from the remote PCM multiplex equipment (see § 3.2.3).

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.737. The consequent actions are as follows:

3.2.1 Service alarm indication generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded at least to the switching and/or signalling multiplex equipment depending upon the arrangements provided. The indication should be given as soon as possible and not later than 2 ms after detection of the relevant fault condition.

This specification, taking into account the specification given in § 2.5, is equivalent to recommending that the average time to detect a loss of frame alignment or a loss of the incoming 2048-kbit/s signal and to give the relevant indication should not be greater than 3 ms.

When using common channel signalling the indication should be forwarded to the switching equipment by means of a separate interface on the PCM multiplex equipment.

3.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the AIS (see General Note below to § 3.2) at 2048-kbit/s input is detected the prompt maintenance alarm indication, associated with loss of frame alignment (see § 3.1.5) and excessive error rate (see § 3.1.6), should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.737 with the two fault conditions.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 3.2.1 and 3.2.2, is left to the discretion of each Administration.

3.2.3 Alarm indication to the remote end transmitted by changing bit 3 of channel time slot 0 from the state 0 to the state 1 in those frames not containing the frame alignment signal. This should be effected as soon as possible.

3.2.4 Transmission suppressed at the analogue voice-frequency outputs.

3.2.5 AIS applied to all 64-kbit/s outputs (see General Note below to § 3.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

3.2.6 AIS applied to relevant time slots in the composite 2048-kbit/s output signal (if supervision of incoming 64-kbit/s signals is provided).

TABLE 2/G.737

Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	Fault conditions (see § 3.1)	Consequent actions (see § 3.2)					
		Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication remote end transmitted	Transmission suppressed at the analogue voice-frequency outputs	AIS applied to all 64 kbit/s outputs	AIS applied to the relevant time slot of the 2048 kbit/s composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes	Yes (if practicable)	Yes (if practicable)	Yes (if practicable)	Yes (if practicable)
	Failure of codec	Yes	Yes	Yes	Yes		
Multiplexer only	Loss of incoming signal at 64 kbit/s input (see Note under § 3.1.3)		Yes				Yes,
Demultiplexer only	Loss of incoming signal at 2048 kbit/s	Yes	Yes	Yes	Yes	Yes	
	Loss of frame alignment	Yes	Yes (see § 3.2.2)	Yes	Yes	Yes	
	Error ratio $1 \cdot 10^{-3}$ alignment signal	Yes	Yes (see § 3.2.2)	Yes	Yes	Yes	
	Alarm indication received from the remote end	Yes					

Note – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present, the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

General Note to § 3.2 – The equivalent binary content of the alarm indication signal (AIS) is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that with a high probability the AIS is detectable even in the presence of random errors having a mean error ratio $1 \cdot 10^{-3}$. Nevertheless, a signal in which all the binary elements, with the exception of the frame alignment signal, are in the state 1, should not be taken as an AIS.

Note – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

4 Signalling

Text as in CCITT Recommendation G.732.

5 Interfaces

The analogue interfaces should be in accordance with Recommendation G.712. The digital interfaces at 2048 kbit/s should be in accordance with Recommendation G.703. The digital interfaces at 64 kbit/s should be of either the codirectional or the contradirectional type specified in Recommendation G.703. The specifications for 64-kbit/s interfaces are not mandatory for channel associated signalling. The interface for external synchronization of the transmitting timing signal should be in accordance with Recommendation G.703.

6 Jitter

6.1 *Jitter at 2048-kbit/s output*

6.1.1 In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 2048-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 100 kHz.

6.1.2 In the case where the transmitting timing signal is derived from an external source the jitter at the 2048-kbit/s output is under study.

6.1.3 In the case where the transmitting timing signal is derived from the incoming 2048-kbit/s signal having no jitter, the jitter at the 2048-kbit/s output is under study.

6.2 *Jitter at 64-kbit/s output*

Under study.

6.3 *Jitter transfer functions*

6.3.1 The jitter transfer function between the 2048-kbit/s incoming and the 2048-kbit/s output signal [see § 1.3 a)] is under study.

6.3.2 The jitter transfer function between 2048-kbit/s incoming signals and the 64 kbit/s output signal is under study.

Recommendation G.738

CHARACTERISTICS OF A SYNCHRONOUS DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 2048 kbit/s

(Geneva, 1980)

This Recommendation gives the characteristics of a synchronous digital multiplex equipment, to combine up to 31 tributary channels at 64 kbit/s in a 2048-kbit/s digital stream. It is foreseen that in the future the need may arise to devote *n* 64-kbit/s time slots to services requiring more than a single 64-kbit/s channel. The additions to this Recommendation to allow this facility (e.g. definition of proper interfaces at $n \times 64$ kbit/s) are under study.

1 General characteristics

1.1 *Bit rate*

The nominal bit rate is 2048 kbit/s. The tolerance on this rate is ± 50 parts per million (ppm).

1.2 *Timing signal*

It should be possible to derive the transmit timing signal from any of the following:

a) from the received 2048-kbit/s signal,

b) from an external source at 2048 kHz (see § 4),

c) from an internal oscillator.

Note 1 – The possibility of also deriving the transmitting timing signal from a 64-kbit/s tributary is under study.

Note 2 – The provision of a timing signal output, available for the purpose of synchronizing other equipments, is an option that might be required depending upon national synchronization arrangements.

2 Frame structure

2.1 *Number of bits per channel time slot*

Eight, numbered from 1 to 8.

2.2 *Number of channel time slots per frame*

Thirty-two, numbered from 0 to 31. The number of bits per frame is 256, and the frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment*

2.3.1 Channel time slots 1 to 31 are assigned to 31 channels at 64 kbit/s.

Note – In case of interconnection with multiplex equipment using time slot 16 for internal purposes, the use of this time slot for a 64-kbit/s tributary could be excluded.

2.3.2 The allocation of the bits of channel time slot 0 is given in Table 1/G.738.

TABLE 1/G.738

Allocation of bits in channel time slot 0

	Bit number							
	1	2	3	4	5	6	7	8
Time slot 0 containing the frame alignment signal	Reserved for international use (see Note 1)	0	0	1	1	0	1	1
		Frame alignment signal (see § 2.4)						
Time slot 0 not containing the frame alignment signal	Reserved for international use (see Note 1)	1 (see § 2.4)	Alarm indication to the remote digital muldex (see § 3.2.2)	Reserved for national use (see Note 2)				

Note 1 – The use will be defined at a later stage. For the moment these bits are fixed at 1.

Note 2 – The bits allocated for national use may not be used internationally. On the digital path crossing the border, they are fixed at 1.

2.4 *Frame alignment signal*

The frame alignment signal occupies positions 2 to 8 in channel time slot 0 of every other frame (see Table 1/G.738).

The frame alignment signal is: 0011011.

In order to avoid simulation of the frame alignment signal by bits 2 to 8 of channel time slot 0 in frames not containing the frame alignment signal, bit 2 in those channel time slots is fixed at 1.

2.5 *Loss and recovery of frame alignment*

Frame alignment will be assumed to have been lost when three or four consecutive frame alignment signals have been received with an error.

Note 1 – In addition to the preceding, in order to limit the effect of imitative frame alignment signals, the following procedure may be used:

Frame alignment will also be assumed to have been lost when bit 2 in time slot 0 in frames not containing the frame alignment signal has been received with an error on three or four consecutive occasions.

Frame alignment will be assumed to have been recovered when the following sequence is detected:

- for the first time, the presence of the correct frame alignment signal;
- the absence of the frame alignment signal in the following frame detected by verifying that bit 2 in channel time slot 0 is a 1.
- for the second time, the presence of the correct frame alignment signal in the next frame.

Note 2 – To avoid the possibility of a state in which no frame alignment can be achieved due to the presence of an imitative frame alignment signal, the following procedure may be used:

When a valid frame alignment signal is detected in frame n, a check should be made to ensure that a frame alignment signal does not exist in frame $n + 1$, and also that a frame alignment signal exists in frame $n + 2$. Failure to meet one or both of these requirements should cause a new search to be initiated in frame $n + 2$.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The digital muldex should detect the following fault conditions:

3.1.1 Failure of power supply.

3.1.2 Loss of the incoming signal at the 64 kbit/s tributary input port.

Note – This detection is not mandatory when contradirectional interfaces are used.

3.1.3 Loss of the incoming signal at 2048 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, the loss of either or both should constitute loss of the incoming signal.

3.1.4 Loss of frame alignment at 2048 kbit/s.

3.1.5 Error ratio, detected in frame alignment signal, exceeding $1 \cdot 10^{-3}$.

3.1.5.1 Criteria for activating the indication of fault condition:

- error ratio $\leq 1 \cdot 10^{-4}$: the probability of activating the indication of fault condition in a few seconds should be less than 10^{-6}.
- error ratio $\geq 1 \cdot 10^{-3}$: the probability of activating the indication of fault condition in a few seconds should be higher than 0.95.

3.1.5.2 Criteria for deactivating the indication of fault condition:

- error ratio $\geqslant 1 \cdot 10^{-3}$: the probability for deactivating the indication of fault condition in a few seconds should be almost 0;
- error ratio $\leqslant 1 \cdot 10^{-4}$: the probability for deactivating the indication of fault condition in a few seconds should be higher than 0.95.

Note – The activating and the deactivating period specified as "a few seconds" is intended to be in the order of 4 to 5 seconds.

3.1.6 Alarm indication received from the remote digital muldex (see § 3.2).

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.738. The consequent actions are as follows:

3.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the AIS (see General Note below to § 3.2) at 2048-kbit/s input is detected, the prompt maintenance alarm indication, associated with loss of frame alignment (see § 3.1.4) and excessive error rate (see § 3.1.5), should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.738 with the two fault conditions.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in § 3.2.1 is left to the discretion of each Administration.

3.2.2 Alarm indication to the remote end transmitted by changing bit 3 of channel time slot 0 from the state 0 to the state 1 in those frames not containing the frame alignment signal. This should be effected as soon as possible.

3.2.3 AIS applied to all 64-kbit/s outputs (see General Note below to § 3.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

3.2.4 AIS applied to relevant time slots in the composite 2048-kbit/s output signal (if supervision of incoming 64-kbit/s signal is provided).

General Note to § 3.2 – The equivalent binary content of the alarm indication signal (AIS) is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that with a high probability the AIS is detectable even in the presence of random errors having a mean error ratio $1 \cdot 10^{-3}$. Nevertheless, a signal in which all the binary elements, with the exception of the frame alignment signal, are in the state 1, should not be taken as an AIS.

Note – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

4 Interfaces

The digital interfaces at 2048 kbit/s should be in accordance with Recommendation G.703.

The digital interfaces at 64 kbit/s should be of either the codirectional or the contradirectional type specified in Recommendation G.703. The interface for external synchronization of the transmitting timing signal should be in accordance with G.703.

5 Jitter

5.1 *Jitter at 2048-kbit/s output*

5.1.1 In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 2048-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 100 kHz.

5.1.2 In the case where the transmitting timing signal is derived from an external source, the jitter at the 2048-kbit/s output is under study.

TABLE 2/G.738

Fault conditions and consequent actions for the 2048-kbit/s synchronous digital multiplex equipment

Equipment part	Fault conditions (see § 3.1)	Consequent actions (see § 3.2)			
		Prompt maintenance alarm indication generated	Alarm indication to the remote end transmitted	AIS applied to all 64-kbit/s outputs	AIS applied to the relevant time slot of the 2048-kbit/s composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes (if practicable)	Yes (if practicable)	Yes (if practicable)
Multiplexer only	Loss of incoming signal at a 64 kbit/s input (see Note under § 3.1.2.)	Yes			Yes
Demultiplexer only	Loss of incoming signal at 2048 kbit/s	Yes	Yes	Yes	
	Loss of frame alignment	Yes (see § 3.2.1)	Yes	Yes	
	Error ratio $1 \cdot 10^{-3}$ alignment signal	Yes (see § 3.2.1)	Yes	Yes	
	Alarm indication received from the remote end				

Note – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if the condition is the only one present. If more than one fault condition is simultaneously present, the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

5.1.3 In the case where the transmitting timing signal is derived from the incoming 2048-kbit/s signal having no jitter, the jitter at the 2048-kbit/s output is under study.

5.2 *Jitter at 64-kbit/s output*

Under study.

5.3 *Jitter transfer functions*

5.3.1 The jitter transfer function between the 2048-kbit/s incoming and the 2048-kbit/s output signal [see § 1.3 a)] is under study.

5.3.2 The jitter transfer function between the 2048-kbit/s incoming signal and the 64-kbit/s output signal is under study.

CHARACTERISTICS OF AN EXTERNAL ACCESS EQUIPMENT OPERATING AT 2048 kbit/s AND OFFERING SYNCHRONOUS DIGITAL ACCESS AT 64 kbit/s

(Geneva, 1980)

This Recommendation gives the characteristics of an equipment (external to a PCM muldex) operating at 2048 kbit/s and providing synchronous insertion/extraction of 64-kbit/s tributaries into/from channel time slots of a 2048-kbit/s composite signal (see Figure 1/G.739). It is foreseen that in the future the need may arise to devote *n* 64-kbit/s time slots to services requiring more than a single 64-kbit/s channel. The additions to this Recommendation to allow this facility (e.g. definition of proper interfaces at $n \times 64$ kbit/s) are under study.

1 General characteristics

1.1 *Bit rate*

The nominal bit rate is 2048 kbit/s. The tolerance on this rate is ± 50 parts per million (ppm).

1.2 *Timing signal*

The timing signal for the insertion side should be derived from the 2048-kbit/s incoming signal at the insertion side (I_0); the timing signal for the extraction side should be derived from the 2048-kbit/s incoming signal at the extraction side (E_1) (see Figure 1/G.739).

Note 1 – Further study is required on the possible need for an internal clock.

Note 2 – The provision of a timing signal output, available for the purpose of synchronizing other equipments, is an option that might be required depending upon national synchronization arrangements.

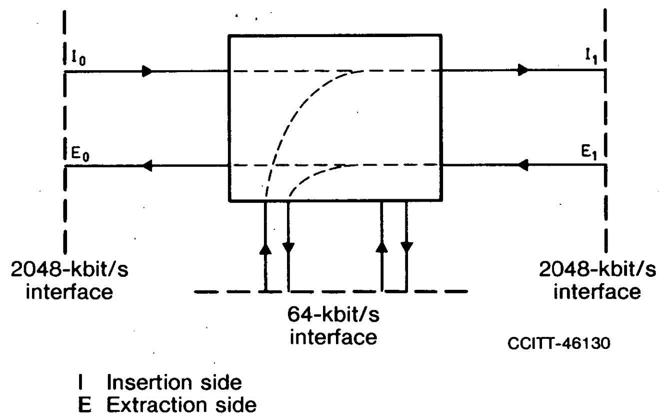


FIGURE 1/G.739

External acces equipment for digital access to channel time slots

2 Frame structure of the 2048-kbit/s signals

2.1 *Number of bits per channel time slot*

Eight, numbered from 1 to 8.

2.2 *Number of channel time slots per frame*

Thirty-two, numbered from 0 to 31. The number of bits per frame is 256, and the frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment*

2.3.1 The number of accessible channel time slots should be four at least, allocated in the following order of priority: 6 – 22 – 14 – 30 – 2 – 18 – 10 – 26 – 4 – 20 – 12 – 28 – 8 – 24 – 5 – 21 – 13 – 29 – 1 – 17 – 9 – 25 – 3 – 19 – 11 – 27 – 7 – 23 – 15 – 31.

The use of time slot 0 is specified in § 2.3.2. Time slots not accessed flow transparently through the equipment.

Note – Further study is required as to whether the binary content of time slots used for the 64-kbit/s access should be replaced by the AIS signal after extraction (direction E_0).

2.3.2 The allocation of the bits of channel time slot 0 is given in Table 1/G.739.

TABLE 1/G.739

Allocation of bits in channel time slot 0

<table>
<tr><th rowspan="2"></th><th colspan="8">Bit number</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td rowspan="2">Time slot 0 containing the frame alignment signal</td><td rowspan="2">Reserved for international use (see Note 1)</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td colspan="7">Frame alignment signal (see § 2.4)</td></tr>
<tr><td>Time slot 0 not containing the frame alignment signal</td><td>Reserved for international use (see Note 1)</td><td>1
(see § 2.4)</td><td>Alarm indication to the remote PCM or digital muldex, not affected by the external access equipment</td><td colspan="5">Reserved for national use (see Note 2)</td></tr>
</table>

Note 1 – The use will be defined at a later stage. For the moment these bits are fixed at 1.

Note 2 – The bits allocated for national use may not be used internationally. On the digital path crossing the border, they are fixed at 1.

Note 3 – The possibility of using one of the spare bits of time slot 0 for transmitting an alarm indication to the remote access equipment is under study.

2.4 *Frame alignment signal*

The frame alignment signal occupies positions 2 to 8 in channel time slot 0 of every other frame (see Table 1/G.739).

The frame alignment signal is: 0011011.

In order to avoid simulation of the frame alignment signal by bits 2 to 8 of channel time slot 0 in frames not containing the frame alignment signal; bit 2 in those channel time slots is fixed at 1.

2.5 *Loss and recovery of frame alignment both at insertion* (I_0) *and extraction* (E_1) *sides*

Frame alignment will be assumed to have been lost when three or four consecutive frame alignment signals have been received with an error.

Note 1 – In addition to the preceding, in order to limit the effect of imitative frame alignment signals, the following procedure may be used:

Frame alignment will also be assumed to have been lost when bit 2 in time slot 0 in frames not containing the frame alignment signal has been received with an error on three or four consecutive occasions.

Frame alignment will be assumed to have been recovered when the following sequence is detected:

- for the first time, the presence of the correct frame alignment signal;
- the absence of the frame alignment in the following frame detected by verifying that bit 2 in channel time slot 0 is a 1;
- for the second time, the presence of the correct frame alignment signal in the next frame.

Note 2 – To avoid the possibility of a state in which no frame alignment can be achieved due to the presence of an imitative frame alignment signal the following procedure may be used:

When a valid frame alignment signal is detected in frame n, a check should be made to ensure that a frame alignment signal does not exist in frame $n + 1$, and also that a frame alignment signal exists in frame $n + 2$. Failure to meet one or both of these requirements should cause a new search to be initiated in frame $n + 2$.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The equipment should detect the following fault conditions:

3.1.1 Failure of power supply.

3.1.2 Loss of incoming signal at a 64-kbit/s tributary input.

Note – This detection is not mandatory when contradirectional interfaces are used.

3.1.3 Loss of the incoming signal at 2048 kbit/s both at insertion (I_0) and extraction (E_1) sides.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, the loss of either or both should constitute loss of the incoming signal.

3.1.4 Loss of frame alignment both at insertion (I_0) and extraction (E_1) sides.

3.1.5 Error ratio, detected in frame alignment signal at both the extraction side (E_1) and insertion side (I_0) exceeding $1 \cdot 10^{-3}$.

Note – The detection of this fault condition at insertion side (I_0) depends on the type of application of this equipment in a network and therefore is not mandatory.

3.1.5.1 Criteria for activating the indication of fault conditions:

- error ratio $\leqslant 1 \cdot 10^{-4}$: the probability of activating the indication of fault condition in a few seconds should be less than 10^{-6}.
- error ratio $\geqslant 1 \cdot 10^{-3}$: the probability of activating the indication of fault condition in a few seconds should be higher than 0.95.

3.1.5.2 Criteria for deactivating the indication of fault condition:

- error ratio $\geqslant 1 \cdot 10^{-3}$: the probability for deactivating the indication of fault condition in a few seconds should be almost 0.
- error ratio $\leqslant 1 \cdot 10^{-4}$: the probability for deactivating the indication of fault condition in a few seconds should be higher than 0.95.

Note – The activating and the deactivating period specified as "a few seconds" is intended to be in the order of 4 to 5 seconds.

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.739. The consequent actions are as follows:

3.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the AIS at the 2048-kbit/s inputs (I_0, E_1) is detected (see General Note below to § 3.2) the prompt maintenance alarm indication associated with loss of frame alignment (see § 3.1.4) and excessive error rate (see § 3.1.5), should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.739 with the two fault conditions.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in § 3.2.1, is left to the discretion of each Administration.

3.2.2 AIS applied to all 64-kbit/s outputs (see General Note below to § 3.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

3.2.3 AIS applied to relevant time slots in the composite 2048-kbit/s output signal at insertion side (I_1) if supervision of the incoming 64-kbit/s signal is provided.

3.2.4 Inhibition of 64-kbit/s digital information insertion.

3.2.5 Both 2048-kbit/s signals are bypassed.

Note – The provision of this consequent action depends on the type of application of this equipment in a network and therefore is not mandatory.

3.2.6 AIS applied to the 2048-kbit/s output, extraction side (E_0).

Note – The provision of this consequent action depends on the type of application of this equipment in a network and therefore is not mandatory.

3.2.7 AIS applied to the 2048-kbit/s output, insertion side (I_1).

Note – The provision of this consequent action depends on the type of this equipment in a network and therefore is not mandatory.

General Note to § 3.2 – The equivalent binary content of the alarm indication signal (AIS) is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that with a high probability the AIS is detectable even in the presence of random errors having a mean error rate of 1 in 10^3. Nevertheless, a signal in which all the binary elements, with the exception of the frame alignment signal, are in the state 1, should not be taken as an AIS.

Note – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

4 Interfaces

The digital interfaces at 2048 kbit/s should be in accordance with Recommendation G.703.

The digital interfaces at 64 kbit/s should be either of the codirectional or the contradirectional type specified in G.703.

5 Jitter

5.1 The jitter at 2048-kbit/s outputs (I_1, E_0) when there is no jitter at the 2048-kbit/s inputs (I_0, E_1) is under study.

5.2 The jitter transfer function between 2048-kbit/s inputs (I_0, E_1) and outputs (I_1, E_0) is under study.

5.3 The jitter at 64-kbit/s outputs when there is no jitter at 2048-kbit/s inputs (E_1) is under study.

5.4 The jitter transfer function between the 2048-kbit/s input (E_1) and the 64-kbit/s output is under study.

TABLE 2/G.739

Fault conditions and consequent actions for the external access equipment

Fault conditions (see § 3.1)		Consequent actions (see § 3.2)				Both 2048-kbit/s signal are bypassed (see Note under § 3.2.5)	AIS applied to the 2048-kbit/s output, extraction side (E_0) (see Note under § 3.2.6)	AIS applied to the 2048-kbit/s output, insertion side (I_1) (see Note under § 3.2.7)
		Prompt maintenance alarms indication generated	AIS applied to 64-kbits output	Inhibition of 64-kbit/s digital information insertion	AIS applied to the relevant time slot of the 2048-kbit/s composite signal at insertion side (I_1)			
Failure of power supply		Yes				Yes	Yes (if practicable)	Yes (if practicable)
Loss of incoming signal at a 64-kbit/s input (see Note under § 3.1.2)		Yes			Yes			
Loss of incoming signal at 2048 kbit/s	Extr.s. (E_1)	Yes	Yes				Yes	
	Ins.s. (I_0)	Yes		Yes				Yes
Loss of frame alignment	Extr.s. (E_1)	Yes (see § 3.2.1)	Yes				Yes	
	Ins.s. (I_0)	Yes (see § 3.2.1)		Yes				Yes
Error ratio $1 \cdot 10^{-3}$ on the frame alignment signal (see Note under § 3.1.5)	Extr.s. (E_1)	Yes (see § 3.2.1)	Yes				Yes	
	Ins.s. (I_0)	Yes (see § 3.2.1)		Yes				Yes

Note – A *Yes* in the table signifies that an action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present, the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

7.4 Principal characteristics of second order multiplex equipments

Recommendation G.741

GENERAL CONSIDERATIONS ON SECOND ORDER MULTIPLEX EQUIPMENTS

(Geneva, 1972; amended at Geneva, 1976 and 1980)

Characteristics of second order PCM and digital multiplex equipments are under study.

The CCITT,

considering

(a) that different primary and second order multiplex equipments exist, depending upon the characteristics of different networks and the various types of signals to be transmitted in those networks;

(b) that, although studies will continue with the aim of reducing the differences between various systems, the existing situation cannot be changed in the near future;

recommends the following

(1) when two countries, both using 2048-kbit/s primary multiplex equipments such as the PCM multiplex equipment according to Recommendation G.732, have to be connected by a digital path at the second order bit rate, that bit rate should be 8448 kbit/s;

(2) when two countries, both using 1544-kbit/s primary multiplex equipments such as the PCM multiplex equipment according to Recommendation G.733, have to be connected by a digital path at the second order bit rate, that bit rate should be 6312 kbit/s.

In the meantime, it is extremely desirable to define a preferred method of interconnecting different systems (see Question 14/XVIII [1]).

Recommendations G.742 and G.743 give the characteristics of second order digital multiplex equipments using positive justification, and Recommendation G.745 gives the characteristics of second order multiplex equipment using positive/zero/negative justification. Recommendation G.744 gives the characteristics of 8448-kbit/s PCM multiplex equipment.

It is recognized, however, that in the evolving digital networks a need may arise for synchronous digital multiplex equipments, especially with the introduction of digital switching. Proposals for such equipment are given in Annex A.

In view of the fact that the frame structure for synchronous digital multiplex equipment (see Annex A) is almost the same as the frame structures contained in Recommendations G.744, G.745 and G.746, the CCITT is committed to studying the possibility of preparing a single Recommendation for these types of equipment. A proposal for such an equipment is given in Annex B.

ANNEX A

(to Recommendation G.741)

Characteristics of synchronous digital multiplex equipment operating at 8448 kbit/s

A.1 *Bit rate*

The nominal bit rate should be 8448 kbit/s.

The tolerance on that rate should be ± 30 parts per million (ppm).

A.2 *Frame structure*

Table A-1/G.741 gives:

– the tributary bit rate and the number of tributaries;
– the number of time slots per frame;
– the time slot numbering scheme;
– the time slot assignment;
– the frame-alignment signal, 14 bits long, distributed into time slots Nos. 0 and 66.

A.3 *Loss and recovery of frame alignment and consequent action*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

As soon as frame alignment has been lost and until it has been recovered a definite pattern should be sent on all tributaries at the output of the demultiplexer. The equivalent binary content of this alarm indication signal (AIS) pattern at 2048 kbit/s is a continuous stream of binary 1s.

TABLE A-1/G.741

8448-kbit/s synchronous digital multiplexing frame structure

Tributary bit rate (kbit/s) [a]	2048
Number of tributaries	4
Frame structure	Time slot number
Frame alignment signal (the first 8 bits out of 14 are 11100110)	0
Frame alignment time slots of the tributaries	1 to 4
Time slots from tributaries	5 to 32
Spare time slot	33
Time slots from tributaries	34 to 65
Frame alignment signal (the last 6 bits out of 14 are 100000)	66
Service bits (bits Nos. 7 and 8)	66
Signalling time slots of the tributaries	67 to 70
Time slots from tributaries	71 to 98
Spare time slot	99
Time slots from tributaries	100 to 131
Frame length	132 time slots
Number of telephone channels	120

[a] The tributary frame structure should be that recommended for the 2048-kbit/s PCM multiplex equipments.

A.4 *Multiplexing method*

Cyclic time-slot interleaving in the tributary numbering order and synchronous multiplexing is recommended. The tributary frame structure should be that recommended for the 2048 kbit/s PCM multiplex equipments. The time slots used for the frame alignment signals of the tributaries should be identified at the multiplexer input and multiplexed into the preassigned time slots, positions Nos. 1 to 4, of the 8448-kbit/s frame.

A.5 *Jitter*

The amount of jitter that should be accepted at the input of the multiplexer and at the input of the demultiplexer, as well as the amount of jitter at the output of the multiplexer and at the output of the demultiplexer, should be studied and specified.

A.6 *Digital interface*

The digital interfaces at 2048 kbit/s and 8448 kbit/s should be in accordance with Recommendation G.703.

A.7 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

A.8 *Service digits*

Two digits per frame are available for service functions. Bit 7 of time-slot No. 66 is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment.

A.9 *Spare time-slots*

Time-slots Nos. 33 and 99 are left for national use. On a digital path crossing an international border the bits of these time slots are fixed at state 1.

ANNEX B

(to Recommendation G.741)

A multi-purpose frame structure for a second order digital system operating at 8448 kbit/s

(Contribution of Administrations of Bulgaria, Czechoslovakia, Cuba, German Democratic Republic, Hungary, Mongolia, Poland, U.S.S.R. and Vietnam)

B.1 *General*

It is possible to create an 8448-kbit/s multi-purpose frame, i.e. suitable for different evident cases of using this bit rate involved in the digital networks. This is of great interest in view of the fact that in the near future digital exchanges operating at 8448 kbit/s will be widely used in digital networks.

The multi-purpose frame proposed is given in Table B-1/G.741. This frame makes it possible to create a new second-order digital system which henceforth may be a single one providing all acceptable modes of operation of future integrated digital networks. The equipment developed using the multi-purpose frame proposed may interwork with the equipment corresponding to Recommendations G.744, G.745, G.746 and to Annex A to this Recommendation.

B.2 *Interworking*

Table B-2/G.741 gives frame structures for second-order digital systems recommended by the CCITT as well as the multi-purpose frame. This table shows the possibilities of interworking of all mentioned second-order digital systems using the bit rate of 8448 kbit/s.

At synchronous and plesiochronous operation the only difference is the usage of bits from 269 to 272 (the last 4 bits of channel time-slot No. 33) and of bits 535 and 536 (the last 2 bits of channel time-slot No. 66). Considering that in all second-order digital systems recommended by the CCITT those bits are provided for national use or are either service bits or spare bits, there are no difficulties in adopting their common usage for all systems.

In the case of asynchronous operation the main feature of the multi-purpose frame proposed lies in the different methods of multiplexing of tributaries (by bits or by channel time slots respectively). For interworking it is necessary to connect a bit-to-octet converter to the input of the equipment corresponding to Recommendation G.745. In this case the bit-to-octet converter connected to the output of the equipment corresponding to Recommendation G.745 should imitate the second part of the frame alignment signal (100 000) in channel time slot No. 66 and if required it should align the phase of the tributaries.

TABLE B-1/G.741

The multi-purpose frame structure for second-order digital systems operating at 8448 kbit/s

Second-order bit rate	8448 kbit/s	
Number of tributaries of 2048 kbit/s	4	
Method of multiplexing of tributaries	By channel time slots at synchronous operation. By octects at asynchronous operation[a]	
Information transmitted	Channel time slot number in the frame	Bit numbers in the frame
Frame alignment signal (the first 8 bits out of 14 are 11100110)	0	1 – 8
Frame alignment signals from the tributaries[a]	1 – 4	9 – 40
Information bits from the tributaries	5 – 32	41 – 264
Justification control bits at asynchronous operation	33	265 – 268
Service bits	—	269 – 272
Information bits from the tributaries	34 – 65	273 – 528
Frame alignment signal (the last 6 bits out of 14 are 100000)[b]	—	529 – 532
Justification control bits at asynchronous operation	66	533 – 534
Alarm bit	—	535
Bit for national use	—	536
Signalling time slots from the tributaries	67 – 70	537 – 568
Information bits from the tributaries	71 – 98	569 – 792
Justification control bits at asynchronous operation	—	793 – 796
Bits from the tributaries available for negative justification	99	797 – 800
Information bits from the tributaries	100 – 103	801 – 832
Bits from the tributaries available for positive justification	—	801, 809, 817, 825
Information bits from the tributaries	104 – 131	833 – 1056
Frame length	132 time slots	1056 bits

a) For interworking of equipments corresponding to Recommendation G.744 and to Recommendations G.746 and G.741 (Annex A) respectively, frame alignment signals of 4 primary digital systems should be imitated in these positions in the equipment corresponding to Recommendation G.746.

b) Only for synchronous operation.

TABLE B-2/G.741

<table>
<tr><th rowspan="2">Bit number</th><th rowspan="2">Channel time slot number</th><th rowspan="2">Recommendations G.744, G.746</th><th rowspan="2">Annex A to G.741</th><th colspan="2">Multi-purpose frame</th><th rowspan="2">Recommendation G.745</th></tr>
<tr><th>Synchronous operation</th><th>Asynchronous operation</th></tr>
<tr><td>1-8</td><td>0</td><td colspan="4">The first 8 bits of FAS (11100110)</td><td>FAS (10111000)</td></tr>
<tr><td>9-40</td><td>1-4</td><td>For national use</td><td colspan="2">T (FAS)</td><td rowspan="2">T (by channel time slots</td><td rowspan="2">T (by bits)</td></tr>
<tr><td>41-264</td><td>5-32</td><td colspan="3">T (by channel time slots)</td></tr>
<tr><td>265-268</td><td rowspan="2">33</td><td rowspan="2">For national use</td><td rowspan="2">Spare channel time slots</td><td>Spare CTS</td><td colspan="2">C_{j1} (JCB)</td></tr>
<tr><td>269-272</td><td colspan="2">Service channel</td><td>Service bits</td></tr>
<tr><td>273-528</td><td>34-65</td><td colspan="4">T (by channel time slots)</td><td>T (by bits)</td></tr>
<tr><td>529-532</td><td rowspan="4">66</td><td colspan="3" rowspan="2">The last 6 bits of FAS (100000)</td><td colspan="2">C_{j2} (JCB)</td></tr>
<tr><td>533-534</td><td>Service bits</td><td rowspan="3">Service bits</td></tr>
<tr><td>535</td><td colspan="2" rowspan="2">Service bits</td><td colspan="2">Alarm bit</td></tr>
<tr><td>536</td><td colspan="2">For national use</td></tr>
<tr><td>537-568</td><td>67-70</td><td colspan="3">T (signalling)</td><td rowspan="2">T (by CTS)</td><td rowspan="2">T (by bits)</td></tr>
<tr><td>569-792</td><td>71-98</td><td colspan="3">T (by CTS)</td></tr>
<tr><td>793-796</td><td rowspan="2">99</td><td rowspan="2">For national use</td><td colspan="2" rowspan="2">Spare channel time slots</td><td colspan="2">C_{j3} (JCB)</td></tr>
<tr><td>797-800</td><td colspan="2">BTNJ</td></tr>
<tr><td>801-804</td><td rowspan="2">100</td><td colspan="3" rowspan="3">T (by channel time slots)</td><td rowspan="3">BTPJ (bits Nos. 801, 809, 817, 825)
T
(by CTS)</td><td>BTPJ</td></tr>
<tr><td>805-808</td><td rowspan="2">T (by bits)</td></tr>
<tr><td>809-1056</td><td>104-131</td></tr>
</table>

BTNJ Bits from tributaries available for negative justification
BTPJ Bits from tributaries available for positive justification
CTS Channel time slot
FAS Frame alignment signal
JCB Justification control bit
T Tributary

Reference

[1] CCITT Question 14/XVIII, Contribution COM XVIII-No. 1, Study Period 1981-1984, Geneva, 1981.

Recommendation G.742

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s AND USING POSITIVE JUSTIFICATION

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 General

The second order digital multiplex equipment using positive justification, described below, is intended for use on digital paths between countries using 2048 kbit/s primary multiplex equipments.

2 Bit rate

The nominal bit rate should be 8448 kbit/s.

The tolerance on that rate should be ± 30 parts per million (ppm).

3 Frame structure

Table 1/G.742 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note – As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the C_{jn}-bits ($n = 1, 2, 3$, see Table 1/G.742).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.742 gives the maximum justification rate per tributary and the nominal justification ratio.

TABLE 1/G.742

8448-kbit/s multiplexing frame structure

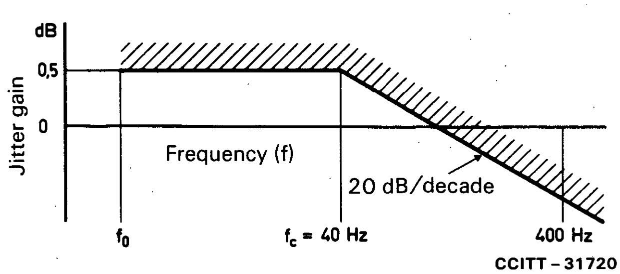
Tributary bit rate (kbit/s)	2048
Number of tributaries	4
Frame structure	Bit number
Frame alignment signal (1111010000) Alarm indication to the remote digital multiplex equipment Bit reserved for national use Bits from tributaries	*Set I* 1 to 10 11 12 13 to 212
Justification control bits C_{j1} (see Note) Bits from tributaries	*Set II* 1 to 4 5 to 212
Justification control bits C_{j2} (see Note) Bits from tributaries	*Set III* 1 to 4 5 to 212
Justification control bits C_{j3} (see Note) Bits from tributaries available for justification Bits from tributaries	*Set IV* 1 to 4 5 to 8 9 to 212
Frame length Bits per tributary Maximum justification rate per tributary Nominal justification ratio	848 bits 206 bits 10 kbit/s 0.424

Note – C_{ji} indicates the *i*th justification control bit of the *j*th tributary.

6 Jitter

6.1 *Jitter transfer characteristic*

A 2048-kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 1/G.742. The equivalent binary content of the test signal should be 1000.



Note – The frequency f_0 should be as low as possible, taking into account the limitations of measuring equipment. Further study is required as to whether the measuring method should be selective or wideband.

FIGURE 1/G.742

6.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.25 UI when measured in the frequency range up to 100 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 18 kHz, a roll-off of 20 dB/decade and an upper limit of 100 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note – For interfaces meeting the national high Q option, detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 700 Hz.

6.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 8448-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 400 kHz.

7 Digital interfaces

The digital interfaces at 2048 kbit/s and 8448 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

9 Service digits

Two bits per frame are available for service functions. Bit 11 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see § 10 below). Bit 12 of Set I is reserved for national use. On the digital path crossing the border, this bit is fixed at 1.

10 Fault conditions and consequent conditions

10.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of an incoming signal at 2048 kbit/s at the input of the multiplexer.

Note – Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 8448 kbit/s at the input of the demultiplexer.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 8448 kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified by Table 2/G.742. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 under § 10.2.5 below) at 8448 kbit/s is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 2/G.742 with the fault condition.

Note – The location and provision of any visual and/or audible alarm activated by this maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I at the 8448-kbit/s output of the multiplexer.

10.2.3 AIS (see Notes 1 and 2 below) applied to all four 2048-kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Notes 1 and 2 below) applied to the 8448-kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 8448-kbit/s signal at the output of the multiplexer, corresponding to the relevant 2048-kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary, should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

TABLE 2/G.742

Fault conditions and consequent actions

Equipment part	Fault conditions (see § 10.1)	Consequent actions (see § 10.2)				
		Prompt maintenance alarm indication generated	Alarm indication to the remote multiplex equipment generated	AIS applied		
				To all the tributaries	To the composite signal	To the relevant time slots of the composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes		Yes, if practicable	Yes, if practicable	
Multiplexer only	Loss of incoming signal on a tributary	Yes				Yes
Demultiplexer only	Loss of incoming signal at 8448 kbit/s	Yes	Yes	Yes		
	Loss of frame alignment	Yes	Yes	Yes		
	Alarm indication received from the remote multiplex equipment					

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Note 1 – The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 – The equivalent binary content of the AIS at 2048 kbit/s and 8448 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio $1 \cdot 10^{-3}$. However, a signal, with all bits except the frame alignment signal in the 1s state, should not be mistaken for an AIS.

10.3 *Time requirements*

The fault detection and the application of the consequent actions listed in §§ 10.2.2 to 10.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

Recommendation G.743

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 6312 kbit/s AND USING POSITIVE JUSTIFICATION

(Geneva, 1972; amended at Geneva, 1976 and 1980)

1 General

The second order digital multiplex equipment using positive justification described below, is intended for use on digital paths between countries using 1544-kbit/s primary multiplex equipments.

2 Bit rate

The nominal bit rate should be 6312 kbit/s.

The tolerance on that rate should be ± 30 parts per million (ppm).

3 Frame structure

Table 1/G.743 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the distributed frame and multiframe alignment signals.

4 Loss and recovery of frame and multiframe alignment and consequent action

The frame alignment recovery time should not exceed 16 ms. The signal to be applied to the tributaries during the out-of-frame-alignment time should be studied.

Once frame alignment is established, multiframe alignment should be recovered in less than 420 microseconds.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the C_{jn}-bits ($n = 1, 2, 3$, see Table 1/G.743).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.743 gives the maximum justification rate per tributary and the nominal justification ratio.

TABLE 1/G.743

6312-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	1544
Number of tributaries	4
Frame structure (see Notes 1 and 2)	Bit number
Bit for multiframe alignment signal (M_j) (see Note 1) Bits from tributaries	*Set I* 1 2 to 49
1st bit for justification control signal (C_{j1}) Bits from tributaries	*Set II* 1 2 to 49
1st bit for frame alignment signal (F_0) (see Note 3) Bits from tributaries	*Set III* 1 2 to 49
2nd bit for justification control signal (C_{j2}) Bits from tributaries	*Set IV* 1 2 to 49
3rd bit for justification control signal (C_{j3}) Bits from tributaries	*Set V* 1 2 to 49
2nd bit for frame alignment signal (F_1) (see Note 3) Bits from tributaries (see Note 4)	*Set VI* 1 2 to 49
Frame length Multiframe length Bits per tributary per multiframe (including justification) Maximum justification rate per tributary Nominal justification ratio	294 bits 1176 bits 288 bits 5367 bit/s 0.334

Note 1 – This frame is repeated 4 times to form a multiframe with frames designated $j = 1, 2, 3, 4$. The multiframe alignment signal is a $011x$-pattern. x may be used as an alarm service digit.
Note 2 – The bits from the second and fourth tributaries are inverted logically before multiplexing with the bits from the first and third tributaries.
Note 3 – The frame alignment is $F_0 = 0$ and $F_1 = 1$.
Note 4 – The bit available for the justification of tributary j is the first time slot of tributary j following F_1 in the jth frame.

6 Jitter

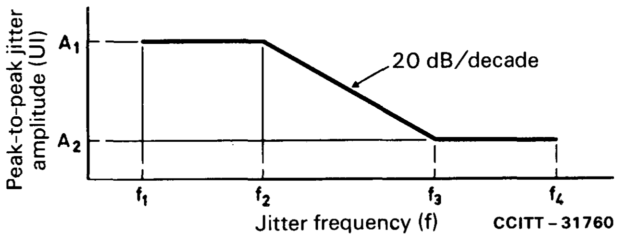
6.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 1/G.743. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length $2^{15} - 1$.

Note – The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.

6.2 *Multiplex signal output jitter*

The jitter at the 6312-kbit/s output of the multiplexer should not exceed 0.01 UI rms.



Input	A_1 (UI)	A_2 (UI)	f_1 (Hz)	f_2 (Hz)	f_3 (kHz)	f_4 (kHz)
1544 kbit/s	2	0.05	10	200	8	40
6312 kbit/s (provisional)	8	0.05	10	200	32	160

UI Unit interval

FIGURE 1/G.743

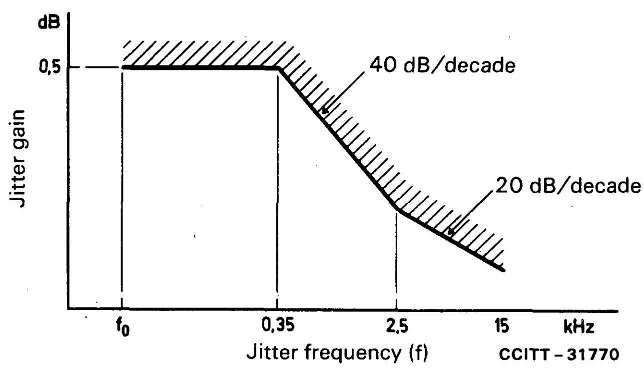
Lower limit of maximum tolerable input jitter

6.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

With no jitter at the input to the multiplexer and demultiplexer, the jitter at the demultiplexer output should not exceed 1/3 unit intervals peak-to-peak.

6.4 *Demultiplexer jitter transfer characteristic*

The gain of the jitter transfer charcteristic should not exceed the limits given in Figure 2/G.743.



Note – The frequency f_0 should be as low as possible taking into account the limitations of measuring equipment.

FIGURE 2/G.743

7 Digital interfaces

The digital interfaces at 1544 kbit/s and 6312 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

9 Service digits

The service digits are reserved for national use.

10 Fault conditions and consequent actions

10.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions.

10.1.1 Failure of power supply.

10.1.2 Loss of frame alignment at the demultiplexer.

It may also be equipped to detect the following fault conditions.

10.1.3 Loss or degradation of incoming 1544-kbit/s signal.

10.1.4 Loss or degradation of incoming 6312-kbit/s signal.

10.1.5 Failure of the multiplex or demultiplex as evidenced by incorrect multiplexing or demultiplexing action.

10.1.6 Failure of standby (if the multiplex is so equipped).

10.2 *Consequent actions*

On the detection of a fault condition, the following appropriate actions should be taken:

10.2.1 For a multiplex equipped with automatic changeover, the consequent actions are specified in Table 2/G.473. For a multiplex so equipped, a switch to a standby is performed in the event of a failure of the multiplex equipment in service. A maintenance alarm is generated if a switch takes place, or if the standby fails. A prompt maintenance alarm is generated if an incoming signal fails, or if service is lost due to inability to complete automatic changeover to the standby.

10.2.2 For a multiplex not equipped with automatic changeover, a prompt maintenance alarm is generated in response to any fault condition detected. Such multiplexers will normally be equipped to detect power failure and loss or degration of incoming signal at the demultiplexer.

10.2.3 The provision of an Alarm Indication Signal (AIS) to the 1544-kbit/s tributary outputs from the demultiplexer is under study. An AIS, suitable for use without special detectors at the primary PCM multiplex might be provided on an optional basis.

TABLE 2/G.743

Fault conditions and consequent actions for a multiplex equipped with automatic changeover

Equipment part	Fault condition (see § 10.1)	Consequent actions (see § 10.2.1)			
		Prompt maintenance alarm indication generated	Deferred maintenance alarm indication generated	Alarm indication to the remote multiplex equipment generated (if so equipped)	Automatic changeover actuated
Multiplexer, demultiplexer	Failure of power supply	No	Yes		Yes
Multiplexer only	Loss or degradation of incoming signal on a tributary	Yes			No
Demultiplexer only	Loss or degradation of incoming signal at 6312 kbit/s		Yes	Yes	No
	Alarm indication received from the remote multiplex equipment (if so equipped)		Yes		

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Recommendation G.744

SECOND ORDER PCM MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s

(Geneva, 1976; amended at Geneva, 1980)

1 General characteristics

1.1 *Fundamental characteristics*

The encoding law used is the A-law as specified in Recommendation G.711. The sampling rate, load capacity and the code are also specified in that Recommendation.

The number of quantized values is 256.

Note – The inversion of bits 2, 4, 6 and 8 is covered by the encoding law and is applicable only to voice-channel time slots.

1.2 *Bit rate*

The nominal bit rate is 8448 kbit/s. The tolerance on this rate is ± 30 parts per million (ppm).

1.3 *Timing signal*

It should be possible to derive the transmitting timing signal of a PCM multiplex equipment from an internal source, from the incoming digital signal and also from an external source.

Note – Further study is required on the effect of jitter of the incoming signal on the timing signal, and on the measures to be taken in case of loss of the incoming signal or the external source.

2 Frame structure

2.1 *Number of bits per channel time slot*

Eight, numbered from 1 to 8.

2.2 *Number of channel time slots per frame*

One hundred and thirty-two, numbered from 0 to 131. The number of bits per frame is 1056, and the frame repetition rate is 8000 Hz.

2.3 *Channel time slot assignment in case of channel-associated signalling*

2.3.1 Channel time slots 5 to 32, 34 to 65, 71 to 98 and 100 to 131 are assigned to 120 telephone channels numbered from 1 to 120.

2.3.2 Channel time slot 0 and the first 6 bits in channel time slot 66 are assigned to framing; the remaining 2 bits in time slot 66 are devoted to services.

2.3.3 Channel time slots 67 to 70 are assigned to channel-associated signalling as covered in § 4 below.

2.3.4 Channel time slots 1 to 4, 33 and 99 are left free for national use.

2.4 *Channel time slot assignment in case of common channel signalling*

2.4.1 Channel time slots 2 to 32, 34 to 65, 67 to 98 and 100 to 131 are available for 127 telephone, signalling or other service channels. By bilateral agreement between the Administrations involved, channel time slot 1 may either be used to provide another telephone or service channel or left free for service purposes within a digital exchange (cf. Recommendation G.746, § 2).

The telephone channels corresponding to channel time slots 1 to 32, 34 to 65 (etc. as above) are numbered from 0 to 127.

2.4.2 Channel time slot 0 and the first 6 bits in channel time slot 66 are assigned to framing; the remaining 2 bits in time slot 66 are assigned to services.

2.4.3 Channel time slots 67 to 70 are in descending order of priority available for common channel signalling as covered in § 4 below.

2.4.4 Channel time slots 33 and 99 are left free for national use.

2.5 *Frame alignment signal*

The frame alignment signal is: 11100110 100000 and occupies the 8 bit-positions in channel time slot 0 and the first 6 bit-positions in channel time slot 66.

2.6 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

2.7 *Service digits*

Bit 7 of time slot 66 is used to convey alarm indication as covered in § 3 below. Bit 8 of time slot 66 and all bits of time slots 33 and 99 are left free for national use and should be fixed at 1 on paths crossing the international border. The same applies to all bits of time slots 1 to 4 in the case of channel-associated signalling.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The PCM multiplex equipment should detect the following fault conditions.

3.1.1 Failure of power supply.

3.1.2 *Failure of codec (except when using single-channel codecs)*

As a minimum requirement, this fault condition should be recognized when, for at least one signal level in the range −21 to −6 dBm0, the signal-to-quantizing noise ratio performance of the local codec is 18 dB or more below the level recommended in Recommendation G.712.

3.1.3 *Loss of incoming signal at the 64 kbit/s input port (time slots 67 to 70)*

Note 1 – The detection of this fault condition is not mandatory when channel associated signalling is used and the signalling multiplex is situated within a few metres of the PCM multiplex equipment.

Note 2 – The detection of this fault condition is not mandatory when contradirectional interfaces are used.

3.1.4 Loss of the incoming signal at 8448 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

3.1.5 Loss of frame alignment.

3.1.6 Excessive error ratio, detected in frame alignment signal.

3.1.6.1 Criteria for activating the indication of fault condition:

- Error ratio $\leqslant 1 \cdot 10^{-4}$

  The probability of activating the indication of fault condition in a few seconds should be less than 10^{-6}.

- Error ratio $\geqslant 1 \cdot 10^{-3}$

  The probability of activating the indication of fault condition in a few seconds should be higher than 0.95.

3.1.6.2 Criteria for deactivating the indication of fault condition:

- Error ratio $\geqslant 1 \cdot 10^{-3}$

  The probability for deactivating the indication of fault condition in a few seconds should be almost 0.

- Error ratio $\leqslant 1 \cdot 10^{-4}$

  The probability for deactivating the indication of fault condition in a few seconds should be higher than 0.95.

Note – The activating and the deactivating period specified as "a few seconds" is intended to be in the order of 4 to 5 seconds.

3.1.7 Alarm indication received from the remote end (see § 3.2.3 below).

3.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.744. The consequent actions are as follows:

3.2.1 Service alarm indication generated to signify that the service provided by the PCM multiplex is no longer available. This indication should be forwarded at least to the switching and/or signalling multiplex equipment depending upon the arrangements provided. The indication should be given as soon as possible and not later than 2 ms after detection of the relevant fault condition.

This specification, taking into account the specification given in § 2.6 above, is equivalent to recommending that the average time to detect a loss of frame alignment or a loss of the incoming 8448-kbit/s signal and to give the relevant indication should not be greater than 3 ms.

When using common channel signalling, the indication should be forwarded to the switching equipment by means of a separate interface on the PCM multiplex equipment.

3.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see General Note below to § 3.2) is detected the prompt maintenance alarm indication, associated with loss of frame alignment (see § 3.1.5 above) and excessive error rate (see § 3.1.6 above), should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 1/G.744 with the two fault conditions.

Note – The location and provision of any visual and/or audible alarms activated by the alarm indications given in §§ 3.2.1 and 3.2.2, is left to the discretion of each Administration.

3.2.3 Alarm indication to the remote end generated by changing bit 7 of channel time slot 66 from the state 0 to the state 1. This should be effected as soon as possible.

3.2.4 Transmission suppressed at the analogue outputs.

3.2.5 AIS applied to time slots 67 to 70, 64-kbit/s outputs when not used for speech (see General Note below to § 3.2). This action should be taken as soon as possible and not later than 2 ms after the detection of the fault condition.

3.2.6 AIS applied to time slots 67 to 70 of the output 8448-kbit/s composite signal when these are not used for speech (if supervision of incoming 64-kbit/s signal is provided).

General Note to § 3.2 – The equivalent binary content of the AIS is a continuous stream of binary 1s.

The strategy for detecting the presence of the AIS should be such that the AIS is detectable, even in the presence of an error ratio $1 \cdot 10^{-3}$. However, a signal with all bits except the frame alignment in the 1s state, should not be mistaken for an AIS.

Note – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

TABLE 1/G.744

Fault conditions and consequent actions for the PCM multiplex equipment

Equipment part	Fault conditions (see § 3.1)	Consequent action (see § 3.2)					
		Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end generated	Transmission suppressed at the analogue outputs	AIS applied to 64-kbit/s outputs (time slots 67 to 70)	AIS applied to time slots 67to70 of the 8448 kbit/s composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	Yes, if practicable
	Failure of codec	Yes	Yes	Yes	Yes		
Multiplexer only	Loss of incoming signal at 64-kbit/s inputs time slots 67 to 70 (see notes under § 3.1.3)		Yes				Yes
Demultiplexer only	Loss of incoming signal at 8448 kbit/s	Yes	Yes	Yes	Yes	Yes	
	Loss of frame alignment	Yes	Yes	Yes	Yes	Yes	
	Error rate 1 in 10^{-3} for the alignment signal	Yes	Yes	Yes	Yes	Yes	
	Alarm indication received from the remote end (bit 7 of time slot 66)	Yes					

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

4 Signalling

The use of channel time slots 67 to 70 is recommended for either common channel or channel-associated signalling as required. The actions described under § 3.2.1 above, consequent to the corresponding fault conditions according to Table 1/G.744, should be applied.

Channel time slots 67 to 70 may be used to provide an interface at 64 kbit/s which shall be suitable for use with either common channel or channel-associated signalling or other services as required. The action described under § 3.2.5 above, consequent to the corresponding fault conditions according to Table 1/G.744, should be applied.

The detailed requirements for the organization of particular signalling systems will be included in the specifications for those signalling systems.

4.1 *Common channel signalling*

Channel time slots 67 to 70 may be used for common channel signalling in a descending order of priority up to a rate of 64 kbit/s. The method of obtaining signal alignment will form part of the particular common channel signalling specification. In this case the 64-kbit/s interface to be used for time slots 67 to 70 should be in accordance with § 5 below and Recommendation G.703.

4.2 *Channel associated signalling*

The recommended arrangement for use of the 64-kbit/s capability of each channel time-slot 67 to 70 for channel-associated signalling is given in the following.

4.2.1 *Multiframe structure*

A multiframe for each 64-kbit/s bit-stream comprises 16 consecutive frames (whose structure is given in § 2 above) and these are numbered from 0 to 15.

The multiframe alignment signal is 0000 and occupies digit time slots 1 to 4 of channel time slots 67 to 70 in frame 0.

4.2.2 *Allocation of channel time slots 67 to 70*

When channel time slots 67 to 70 are used for channel associated signalling, they provide four 64-kbit/s digital paths which are subdivided into lower rate paths using the multiframe alignment signal as a reference. Details of the bit allocation are given in Table 2/G.744.

TABLE 2/G.744

Frame \ Channel time-slot	67		68		69		70	
0	0000*xyxx*		0000*xyxx*		0000*xyxx*		0000*xyxx*	
1	*abcd* channel 1	*abcd* channel 16	*abcd* channel 31	*abcd* channel 46	*abcd* channel 61	*abcd* channel 76	*abcd* channel 91	*abcd* channel 106
15	*abcd* channel 15	*abcd* channel 30	*abcd* channel 45	*abcd* channel 60	*abcd* channel 75	*abcd* channel 90	*abcd* channel 105	*abcd* channel 120

x = spare bit to be made 1 if not used.
y = bit used to indicate loss of multiframe alignment (see § 4.2.4.2.3 of Recommendation G.732).

When bits b, c or d are not used they should have the value:
$b = 1$
$c = 0$
$d = 1$

It is recommended that the combination 0000 of bits a, b, c and d should not be used for signalling purposes for channels 1-15, 31-45, 61-75 and 91-125.

This bit allocation provides four 500-bit/s signalling channels designated *a*, *b*, *c* and *d* for each telephone channel. With this arrangement the signalling distortion of each signalling channel introduced by the PCM transmission system, will not exceed ± 2 ms.

4.2.3 *Loss and recovery of multiframe alignment*

For multiframe alignment each 64-kbit/s channel should be treated separately. For each channel, multiframe alignment should be assumed to have been lost when two consecutive multiframe alignment signals have been received with an error.

Multiframe alignment should be assumed to have been recovered as soon as the first correct multiframe signal is detected.

Note – To avoid a condition of spurious multiframe alignment, the following procedure may be used, in addition to the above:

- Multiframe alignment should be assumed to have been lost when, for a period of one or two multiframes, all the bits in the relevant channel time slots 67, 68, 69 or 70 are at the state 0.
- Multiframe alignment should be assumed to have been recovered, only when at least one bit in the state 1 is present in the relevant time slots 67, 68, 69 or 70 preceding the multiframe alignment signal first detected.

4.2.4 *Fault conditions and consequent actions*

The fault conditions and consequent actions for each 64-kbit/s signalling channel and for each signalling multiplex equipment are the same as recommended in Recommendation G.732, § 4.2.4.

5 Interfaces

The analogue interfaces should be in accordance with Recommendatin G.712.

The digital interfaces should be in accordance with Recommendation G.703.

The specifications for 64-kbit/s interfaces are not mandatory for channel associated signalling.

6 Jitter

6.1 *Multiplex signal output jitter at 8448-kbit/s output*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 8448-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 20 Hz to f_4 = 400 kHz.

6.2 *Jitter at 64 kbit/s output*

Under study.

Recommendation G.745

SECOND ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 8448 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1976; amended at Geneva, 1980)

1 General

The second order digital multiplex equipment using positive/zero/negative justification, considered below, is intended for use on digital paths between countries using 2048 kbit/s primary multiplex equipments, such as the PCM multiplex equipment described in Recommendation G.732 or any identical equipment.

2 Bit rate

The nominal bit rate should be 8448 kbit/s. The tolerance on that rate should be ± 30 parts per million (ppm).

3 Frame structure

Table 1/G.745 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

4 Loss and recovery of frame alignment and consequent action

Loss of frame alignment should be assumed to have taken place when five consecutive frame alignment signals have been incorrectly received in their predicted positions.

Recovery of frame alignment should take place in the case of receiving without errors at least two consecutive frame signals in their predicted positions.

As soon as frame alignment has been lost and until it has been recovered, a definite pattern should be sent to all tributaries from the output of the demultiplexer. The equivalent binary content of this pattern, called the Alarm Indication Signal (AIS), at 2048 kbit/s is a continuous stream of binary 1s.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive/zero/negative justification with two-command control are recommended.

The justification control signal should be distributed and use the C_{jn}-bits ($n = 1, 2, 3$, see Table 1/G.745. Corection of one error in command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000 transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame. Bits 5, 6, 7 and 8 in Set IV (see Table 1/G.745) are used for negative justification of tributaries 1, 2, 3 and 4 respectively, and bits 9 to 12 for positive justification of the same tributaries.

Table 1/G.745 gives the maximum justification rate per tributary.

TABLE 1/G.745

8448-kbit/s digital multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	2048
Number of tributaries	4
Frame structure	Bit number
	Set I
Frame alignment signal (11100110)	1 to 8
Bits from tributaries	9 to 264
	Set II
Justification control bits C_{j1} (see Note)	1 to 4
Bits for service functions	5 to 8
Bits from tributaries	9 to 264
	Set III
Justification control bits C_{j2} (see Note)	1 to 4
Spare bits	5 to 8
Bits from tributaries	9 to 264
	Set IV
Justification control bits C_{j3} (see Note)	1 to 4
Bits from tributaries available for negative justification	5 to 8
Bits from tributaries available for positive justification	9 to 12
Bits from tributaries	13 to 264
Frame length	1056 bits
Frame duration	125 μs
Bits per tributary	256
Maximum justification rate per tributary	8 kbit/s

Note – C_{jn} indicates *n*th justification control bit of the *j*th tributary.

6 Jitter

The amount of jitter that should be accepted at the input of the multiplexer and at the input of the demultiplexer, as well as the amount of jitter at the output of the multiplexer and at the output of the demultiplexer should be studied and specified.

7 Digital interface

The digital interfaces at 2048 kbit/s and 8448 kbit/s should be in accordance with Recommendation G.703.

8 Timing signal

It might be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal one.

9 Service digits

Some spare bits per frame are available for service functions (bits from 5 to 8 in Set II) for national and international use. Utilisation of these bits is under study.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of incoming signal at 2048 kbit/s at the input of the multiplexer.

Note – When using separate circuits for the digital signal and the timing signal, loss of either or both should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 8448 kbit/s at the input of the demultiplexer.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – When using separate circuits for the digital signal and the timing signal, loss of either or both should constitute loss of the incoming signal.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 8448-kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

After detection of a fault condition appropriate actions should be taken as specified in Table 2/G.745. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to designate that the performance is below acceptable standards and maintenance attention is required locally. When detecting the AIS at the 8448-kbit/s input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be prohibited (see Note 1 below).

Note – The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 5 of set IV at the 8448-kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all the four 2048-kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 8448-kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 8448-kbit/s signal at the multiplexer output corresponding to the relevant 2048-kbit/s tributary.

Note 1 – The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 – The equivalent binary content of the AIS at 2048 kbit/s and 8448 kbit/s is a continuous stream of binary 1s.

TABLE 2/G.745

Fault conditions and consequent actions

Equipment part	Fault conditions (see § 10.1)	Consequent actions (see § 10.2)				
		Prompt maintenance alarm indication generated	Alarm indication to the remote multiplexer generated	AIS applied		
				To all the tributaries	To the composite signal	To the relevant time slots of the composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	
Multiplexer only	Loss of incoming signal on a tributary	Yes				Yes
Demultiplexer only	Loss of incoming signal at 8448 kbit/s	Yes	Yes	Yes		
	Loss of frame alignment	Yes	Yes	Yes		
	AIS received from the remote multiplexer					

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

CHARACTERISTICS OF 8448-kbit/s FRAME STRUCTURE FOR USE WITH DIGITAL EXCHANGES

(Geneva, 1976)

1 General characteristics

The multiplex structure described in this Recommendation is suitable for use on 8448-kbit/s digital paths which terminate at digital exchanges. The structure is compatible with that of the PCM secondary multiplex described in Recommendation G.744 and is applicable to digital paths which connect such PCM multiplex equipments to exchanges and to digital paths which interconnect digital exchanges.

Some of the characteristics of this multiplex structure are identical to those in Recommendation G.744 and are covered by cross references to that Recommendation.

1.1 *Fundamental characteristics*

The multiplex structure contains 132 time-slots, each of 64 kbit/s, of which 128 are switchable. In time slots allocated to telephony, speech will be encoded according to Recommendation G.711. Time slots allocated to other services may need to be utilized in a agreed manner (e.g Recommendation X.50 [1] for synchronous date services).

1.2 *Bit rate*

The nominal bit rate is 8448 kbit/s. This rate will be controlled to within at least ± 30 parts per million at the transmitting end for each direction of transmission.

1.3 *Timing signal*

The timing signal is an 8448-kHz signal from which the bit rate is derived.

1.3.1 *Timing in a non-synchronous network*

For a PCM multiplex equipment, the timing signal will be derived from the incoming timing signal at the receive side. For a digital exchange, the transmitting timing will be derived from a clock within the digital exchange.

1.3.2 *Timing in a synchronous network*

In case of synchronous operation of the network, a network synchronization system will maintain the timing signal or clocks within agreed timing limits.

1.4 *Interfaces*

Refer to Recommendations G.744, § 5 and G.703. No interface, internal to the switch, will be recommended.

1.5 *Transmission performance*

The transmission performance of the digital path will be the same as that for 8448-kbit/s digital paths between secondary PCM and/or digital multiplex equipments.

2 Frame structure

The frame structure, frame alignment procedures, and normally the time-slot assignment will be as defined in Recommendation G.744.

Where signalling capacity is required between exchanges, time-slots 67, 68, 69 and 70 may be utilized for common channel signalling in this order of descending priority. Those channels not used for common channel signalling can be used for speech or other purposes.

Note – If a time slot will be dedicated to service purposes internal to the switch, it will be time-slot 1.

3 Fault conditions and consequent actions

3.1 *Fault conditions*

The PCM multiplex equipment should detect the fault conditions mentioned in Recommendation G.744, § 3.1.

The digital exchange terminal equipment, should detect the following fault conditions.

3.1.1 Failure of power supply.

3.1.2 Loss of the incoming signal at 8448 kbit/s.

Note 1 – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

Note 2 – Where separate circuits are used for the digital signal and the timing signal, then loss of either or both should constitute loss of the incoming signal.

3.1.3 Loss of frame alignment.

3.1.4 Excessive error rate detected in the frame alignment signal. The criteria for activating and deactivating this fault condition are given in Recommendation G.744, § 3.1.6.

3.1.5 Alarm indication received from the remote end (See § 3.2.3 below).

3.2 *Consequent actions*

Further to the detection of a fault condition, for PCM multiplexing equipment appropriate actions should be taken as specified by Table 1/G.746 and Recommendation G.744, § 3.2. The consequent actions for the digital exchange are specified by Table 1/G.746 and are as follows:

3.2.1 Service alarm indication generated to signify that the service provided by the exchange terminal (ET) is no longer available. This indication should be given by the ET as soon as possible and not later than 2 ms after the detection of the relevant fault condition.

This specification, taking into account the specification given in Recommendation G.744, § 2.6 is equivalent to recommend that the average time to detect a loss of frame alignment and to give the relevant fault indication should not be greater than 3 ms.

3.2.2 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 1 below) is detected, the prompt maintenance alarm indication, associated with loss of frame alignment and excessive error rate in the frame alignment pattern, should be inhibited.

3.2.3 Alarm indication to the remote end generated by changing bit 7 of channel time-slot 66 from the state 0 to the state 1. This should be effected as soon as possible.

3.2.4 Alarm Indication Signal (see Note 1) applied in all received time-slots containing speech, data and/or signalling. This action should be taken as soon as possible and not later than 2 ms after detection of the fault conditions mentioned in §§ 3.1.1, 3.1.2, 3.1.3 and 3.1.4 above.

Note 1 – The equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1s.

Note 2 – All timing requirements quoted apply equally to restoration, subsequent to the fault condition clearing.

Note 3 – The utilization of these indications will depend upon the switching and signalling arrangements provided nationally. Separate indications for some of the fault conditions listed may be provided nationally if required. The reaction of the processing equipment on the fault indication and the times within which the service and maintenance alarms should be provided need further study.

TABLE 1/G.746

Fault conditions and consequent actions for the digital exchange

Fault conditions (see § 3.1)	Consequent actions (see § 3.2)			
	Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to the remote end generated	AIS applied in the ET
Failure of power supply	Yes	Yes	Yes, if practicable	Yes, if practicable
Loss of incoming signal at 8448 kbit/s	Yes	Yes	Yes	Yes
Loss of frame alignment	Yes	Yes	Yes	Yes
Error rate 1 in 10^3 for the alignment signal	Yes	Yes	Yes	Yes
Alarm indication received from the remote end	Yes			

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Reference

[1] CCITT Recommendation *Fundamental parameters of a multiplexing scheme for the international interface between synchronous data networks*, Vol. VIII, Fascicle VIII.3, Rec. X.50.

7.5 Principal characteristics of higher order multiplex equipments

Recommendation G.751

DIGITAL MULTIPLEX EQUIPMENTS OPERATING AT THE THIRD ORDER BIT RATE OF 34 368 kbit/s AND THE FOURTH ORDER BIT RATE OF 139 264 kbit/s AND USING POSITIVE JUSTIFICATION

(Geneva, 1976; amended at Geneva, 1980)

1 General characteristics

1.1 There should be a 4th-order bit rate of 139 264 kbit/s in the digital hierarchy which is based on the 2nd-order bit rate of 8448 kbit/s.

There should be two methods of achieving the 4th-order bit rate:

Method 1 – by using a 3rd-order bit rate of 34 368 kbit/s in the digital hierarchy.

Method 2 – by directly multiplexing sixteen digital signals at 8448 kbit/s.

The digital signals at the bit rate of 139 264 kbit/s obtained by these two methods should be identical.

1.2 The existence of the above two methods implies that the use of the bit rate of 34 368 kbit/s should not be imposed on an Administration that does not wish to realize the corresponding equipment.

1.3 In accordance with the above two methods, the following realizations of digital multiplex equipments using positive justification are recommended:

Method 1 – Realization by separate digital multiplex equipments: one type which operates at 34 368 kbit/s and multiplexes four digital signals at 8448 kbit/s; the other type which operates at 139 264 kbit/s and multiplexes four digital signals at 34 368 kbit/s.

The multiplexing for the 34 368-kbit/s digital multiplex equipment is recommended in 1.4 below, while further specification of this equipment is given in § 2 below.

The multiplexing for the 139 264-kbit/s digital multiplex equipment is recommended in 1.5 below, while further specification of this equipment is given in § 3 below.

Method 2 – Realization by a single digital multiplex equipment which operates at 139 264 kbit/s and multiplexes sixteen digital signals at 8448 kbit/s.

The digital multiplexing for the 139 264-kbit/s bit rate should be achieved by multiplexing, in accordance with § 1.5 below, four digital signals at 34 368 kbit/s, each of which is obtained by multiplexing, in accordance with § 1.4 below, four digital signals at 8448 kbit/s. Further specification of this equipment is given in § 4 below.

1.4 *Multiplexing four digital signals at 8448 kbit/s*

1.4.1 *Bit rate*

The nominal bit rate should be 34 368 kbit/s.

The tolerance on that rate should be ± 20 parts per million (ppm).

1.4.2 *Frame structure*

Table 1/G.751 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

1.4.3 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note – As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

1.4.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended. The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 1/G.751). Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 1/G.751 gives the maximum justification rate per tributary and the nominal justification ratio.

TABLE 1/G.751

34 368-kbits/s multiplexing frame structure

Tributary bit rate (kbit/s)	8448
Number of tributaries	4
Frame structure	Bit number
Frame alignment signal (1111010000) Alarm indication to the remote digital multiplex equipment Bit reserved for national use Bits from tributaries	*Set I* 1 to 10 11 12 13 to 384
Justification service bits C_{j1} (see Note) Bits from tributaries	*Set II* 1 to 4 5 to 384
Justification service bits C_{j2} (see Note) Bits from tributaries	*Set III* 1 to 4 5 to 384
Justification service bits C_{j3} (see Note) Bits from tributaries available for justification Bits from tributaries	*Set IV* 1 to 4 5 to 8 9 to 384
Frame length Bits per tributary Maximum justification rate per tributary Nominal justification ratio	1536 bits 378 bits 22 375 bit/s 0.436

Note – C_{jn} indicates the *n*th justification service bit of the *j*th tributary.

1.4.5 *Service digits*

Two bits per frame are available for service functions. Bit 11 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see §§ 2.5 and 4.5 below). Bit 12 of Set I is reserved for national use. On a digital path crossing the border, this bit is fixed at 1.

1.5 *Multiplexing four digital signals at 34 368 kbit/s*

1.5.1 *Bit rate*

The nominal bit rate should be 139 264 kbit/s. The tolerance on that rate should be ± 15 parts per million (ppm).

1.5.2 *Frame structure*

Table 2/G.751 gives:

- the tributary bit rate and the number of tributaries:
- the number of bits per frame;
- the bits numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

TABLE 2/G.751

139 264-kbits/s multiplexing frame structure

Tributary bit rate (kbit/s)	34 368
Number of tributaries	4
Frame structure	Bit number
	Set I
Frame alignment signal (111110100000)	1 to 12
Alarm indication to the remote digital multiplex equipment	13
Bits reserved for national use	14 to 16
Bits from tributaries	17 to 488
	Sets II to V
Justification service bits C_{jn} (n = 1 to 4) (see Note)	1 to 4
Bits from tributaries	5 to 488
	Set VI
Justification service bits C_{j5} (see Note)	1 to 4
Bits from tributaries available for justification	5 to 8
Bits from tributaries	9 to 488
Frame length	2928 bits
Bits per tributary	723 bits
Maximum justification rate per tributary	47 560 bit/s
Nominal justification ratio	0.419

Note – C_{jn} indicates the *n*th justification service bit of the *j*th tributary.

1.5.3 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note – As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

1.5.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended. The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, 4, 5, see Table 2/G.751). Positive justification should be indicated by the signal 11111, no justification by the signal 00000. Majority decision is recommended.

Table 2/G.751 gives the minimum justification rate per tributary and the nominal justification ratio.

1.5.5 *Service digits*

Four bits per frame are available for service functions. Bit 13 of Set I is used to transmit an alarm indication to the remote multiplex equipment when specific fault conditions are detected in the multiplex equipment (see §§ 3.5 and 4.5 below). Bits 14 to 16 of Set I are reserved for national use. On a digital path crossing the border, these bits are fixed at 1.

2 Digital multiplex equipment operating at 34 368 kbit/s and multiplexing four tributaries at 8448 kbit/s

2.1 *Multiplexing*

The multiplexing for the 34 368-kbit/s bit rate should be in accordance with § 1.4 below.

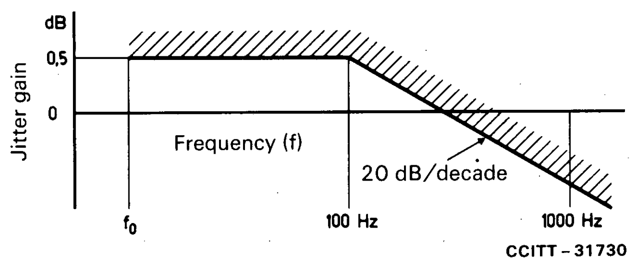
2.2 *Digital interfaces*

The digital interfaces at 8448 kbit/s and 34 368 kbit/s should be in accordance with Recommendation G.703.

2.3 *Jitter*

2.3.1 *Jitter transfer characteristic*

An 8448-kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 1/G.751. The equivalent binary content of the test signal should be 1000.



Note – The frequency f_0 should be as low as possible, taking into account the limitations of measuring equipment. Further study is required as to whether the measuring method should be selective or wideband.

FIGURE 1/G.751

2.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.25 UI when measured in the frequency range up to 400 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 3 kHz, a rolloff of 20 dB/decade and an upper limit of 400 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note – For interfaces meeting the national low Q option detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 80 kHz.

2.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 34 368-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 100 Hz to f_4 = 800 kHz.

2.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

2.5 *Fault conditions, and consequent actions*

2.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

2.5.1.1 Failure of power supply

2.5.1.2 Loss of an incoming signal at 8448 kbit/s at the input of the multiplexer.

Note – Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

2.5.1.3 Loss of the incoming signal at 34 368 kbit/s at the input of the demultiplexer.

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

2.5.1.4 Loss of frame alignment.

2.5.1.5 Alarm indication received from the remote multiplex equipment at the 34 368-kbit/s input of the demultiplexer (see § 2.5.2.2 below)

2.5.2 *Consequent actions*

Further to detection of a fault condition, actions should be taken as specified by Table 3/G.751. The consequent actions are as follows:

2.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 under § 2.5.2.5) at 34 368 kbit/s is detected at the input of the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 3/G.751 with the fault condition.

Note – The location and provision of any visual and/or audible alarm activated by this maintenance alarm indication is left to the discretion of each Administration.

2.5.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I at the 34 368-kbit/s output of the multiplexer.

2.5.2.3 AIS (see Notes 1 and 2 below) applied to all four 8448-kbit/s tributary outputs from the demultiplexer.

2.5.2.4 AIS (see Notes 1 and 2 below) applied to the 34 368-kbit/s output of the multiplexer.

2.5.2.5 AIS (see Note 2 below) applied to time slots of the 34 368-kbit/s signal at the output of the multiplexer, corresponding to the relevant 8448-kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

Note 1 – The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 – The equivalent binary content of the AIS (AIS) at 8448 kbit/s and 34 368 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio $1 \cdot 10^{-3}$. However a signal with all bits except the frame alignment signal in the 1 state, should not be mistaken as an AIS.

2.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 2.5.2.2 to 2.5.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

TABLE 3/G.751

Fault conditions and consequent actions

<table>
<tr><th rowspan="3">Equipment part</th><th rowspan="3">Fault conditions (see §§ 2.5.1 or 3.5.1)</th><th colspan="5">Consequent actions (see §§ 2.5.2 or 3.5.2)</th></tr>
<tr><th rowspan="2">Prompt maintenance alarm indication generated</th><th rowspan="2">Alarm indication to the remote multiplex equipment generated</th><th colspan="3">AIS applied</th></tr>
<tr><th>To all the tributaries</th><th>To the composite signal</th><th>To the relevant time slots of the composite signal</th></tr>
<tr><td>Multiplexer and demultiplexer</td><td>Failure of power supply</td><td>Yes</td><td></td><td>Yes, if practicable</td><td>Yes, if practicable</td><td></td></tr>
<tr><td>Multiplexer only</td><td>Loss of incoming signal on a tributary</td><td>Yes</td><td></td><td></td><td></td><td>Yes</td></tr>
<tr><td rowspan="3">Demultiplexer only</td><td>Loss of incoming signal</td><td>Yes</td><td>Yes</td><td>Yes</td><td></td><td></td></tr>
<tr><td>Loss of frame alignment</td><td>Yes</td><td>Yes</td><td>Yes</td><td></td><td></td></tr>
<tr><td>Alarm indication received from the remote multiplex equipment</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

3 Digital multiplex equipment operating at 139 264 kbit/s and multiplexing four tributaries at 34 368 kbit/s

3.1 *Multiplexing*

The multiplexing for the 139 264-kbit/s bit rate should be in accordance with § 1.5 above.

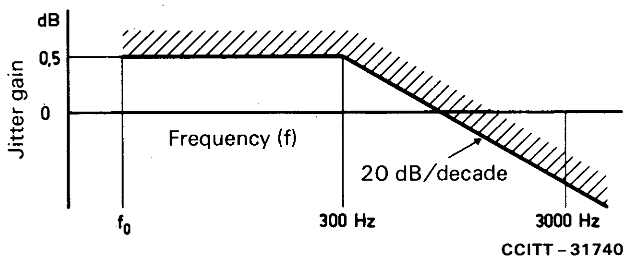
3.2 *Digital interfaces*

The digital interfaces at 34 368 kbit/s and 139 264 kbit/s should be in accordance with Recommendation G.703.

3.3 *Jitter*

3.3.1 *Jitter transfer characteristic*

A 34 368-kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 2/G.751. The equivalent binary content of the test signal should be 1000.



Note – The frequency f_0 should be as low as possible, taking into account the limitations of measuring equipment. Further study is required as to whether the measuring method should be selective or wideband.

FIGURE 2/G.751

3.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.3 UI when measured in the frequency range up to 800 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cut off frequency of 10 kHz, a roll off of 20 dB/decade and an upper limit of 800 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

3.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 139 264-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 200 Hz to f_4 = 3500 kHz.

3.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from internal source.

3.5 *Fault conditions and consequent actions*

3.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

3.5.1.1 Failure of power supply.

3.5.1.2 Loss of an incoming signal at 34 368 kbit/s at the input of the multiplexer.

3.5.1.3 Loss of the incoming signal at 139 264 kbit/s at the input of the demultiplexer.

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

3.5.1.4 Loss of frame alignment.

3.5.1.5 Alarm indication received from the remote multiplex equipment at the 139 264 kbit/s input of the demultiplexer (see § 3.5.2.2 below).

3.5.2 *Consequent actions*

Further to detection of a fault condition actions should be taken as specified by Table 3/G.751. The consequent actions are as follows:

3.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 below) at 139 264 kbit/s is detected at the input to the demultiplexer, the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 3/G.751 with the fault condition.

3.5.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 13 of Set I at the 139 264-kbit/s output of the multiplexer.

3.5.2.3 AIS (see Notes 1 and 2 below) applied to all four 34 368-kbit/s tributary outputs from the demultiplexer.

3.5.2.4 AIS (see Notes 1 and 2 below) applied to the 139 264-kbit/s output of the multiplexer.

3.5.2.5 AIS (see Note 2 below) applied to time slots of the 139 264-kbit/s signal at the output of the multiplexer corresponding to the relevant 34 368-kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for the tributary.

Note 1 – The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 – The equivalent binary content of the AIS at 34 368 kbit/s and 139 264 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio $1 \cdot 10^{-3}$. However a signal, with all bits except the frame alignment signal in the 1 state, should not be mistaken for an AIS.

3.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 3.5.2.2 to 3.5.2.5, including the detection of AIS, should be completed within a time limit of 1 ms.

4 Digital multiplex equipment operating at 139 264 kbit/s and multiplexing sixteen tributaries at 8448 kbit/s

4.1 *Multiplexing*

The multiplexing for the 139 264-kbit/s bit rate should be achieved by multiplexing, in accordance with § 1.5 above, four digital signals at 34 368 kbit/s, each of which is obtained by multiplexing, in accordance with § 1.4 above, four digital signals at 8448 kbit/s.

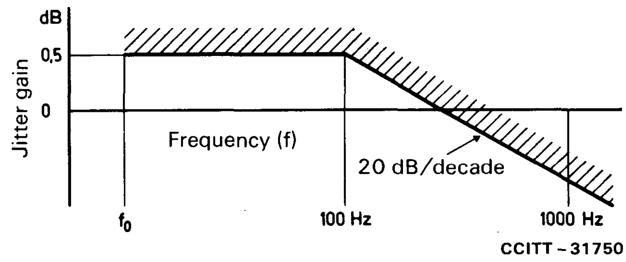
4.2 *Digital interfaces*

The digital interfaces at 8448 kbit/s and 139 264 kbit/s should be in accordance with Recommendation G.703.

4.3 *Jitter*

4.3.1 *Jitter transfer characteristic*

A 8448-kbit/s signal, modulated by sinusoidal jitter, should be subject to a muldex jitter transfer characteristic within the gain/frequency limits given in Figure 3/G.751. The equivalent binary content of the test signal should be 1000.



Note – The frequency f_0 should be as low as possible, taking into account the limitations of measuring equipment. Further study is required as to whether the measuring method should be selective or wideband.

FIGURE 3/G.751

4.3.2 *Tributary output jitter*

The peak-to-peak jitter at a tributary output in the absence of input jitter should not exceed 0.35 UI when measured in the frequency range up to 400 kHz.

When measured with an instrument incorporating a bandpass filter having a lower cutoff frequency of 3 kHz, a rolloff of 20 dB/decade and an upper limit of 400 kHz, the peak-to-peak output jitter should not exceed 0.05 UI with a probability of 99.9% during a measurement period of 10 s.

Note – For interfaces meeting the national low Q option, detailed in Recommendation G.703, the lower cutoff frequency for the above measurement should be 80 kHz.

4.3.3 *Multiplex signal output jitter*

In the case where the transmitting timing signal is derived from an internal oscillator, the peak-to-peak jitter at the 139 264-kbit/s output should not exceed 0.05 UI when it is measured within the frequency range from f_1 = 100 Hz to f_4 = 3500 kHz.

4.4 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

4.5 *Fault conditions and consequent actions*

4.5.1 *Fault conditions*

The digital multiplex equipment should detect the following fault conditions:

4.5.1.1 Failure of power supply.

4.5.1.2 Loss of an incoming signal at 8448 kbit/s at the input of the multiplexer.

Note – Where separate circuits are used for the digital signal and the timing signal then loss of either or both should constitute loss of the incoming signal.

4.5.1.3 Loss of the incoming signal at 139 264 kbit/s at the input of the demultiplexer.

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

4.5.1.4 Loss of frame alignment of the signal at 139 264 kbit/s at the input of the demultiplexer.

4.5.1.5 Loss of frame alignment of a signal at 34 368 kbit/s within the demultiplexer.

4.5.1.6 Alarm indication received from the remote multiplex equipment at the 139 264-kbit/s input of the demultiplexer (see § 4.5.2.2 below).

4.5.1.7 Alarm indication received from the remote multiplex equipment on a signal at 34 368 kbit/s within the demultiplexer (see § 4.5.2.3 below).

4.5.2 *Consequent actions*

Further to detection of a fault condition, actions should be taken as specified by Table 4/G.751. The consequent actions are as follows:

4.5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally. When the Alarm Indication Signal (AIS) (see Note 2 below) at 139 264 kbit/s or 34 368 kbit/s is detected by the demultiplexer, the prompt maintenance alarm indication associated with the corresponding loss of frame alignment should be inhibited, while the rest of the consequent actions are in accordance with those associated in Table 4/G.751 with the fault condition.

Note – The location and provision of any visual and/or audible alarms activated by the maintenance alarm indication is left to the discretion of each Administration.

4.5.2.2 Alarm indication on the 139 264-kbit/s signal to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 13 of Set I at the 139 264-kbit/s output of the multiplexer.

4.5.2.3 Alarm indication on a 34 368-kbit/s signal to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 11 of Set I on the 34 368-kbit/s signal into the multiplexer.

4.5.2.4 AIS (see Notes 1 and 2 below) applied to all sixteen 8448-kbit/s tributary outputs from the demultiplexer.

4.5.2.5 AIS (see Notes 1 and 2 below) applied to all four 8448-kbit/s relevant tributary outputs from the demultiplexer.

4.5.2.6 AIS (see Notes 1 and 2 below) applied to the 139 264-kbit/s output of the multiplexer.

4.5.2.7 AIS (see Note 2 below) applied to the time slot of the 139 264 kbit/s at the output of the multiplexer, corresponding to the relevant 8448-kbit/s tributary.

The method of transmitting the AIS at the output port of the multiplexer in time slots corresponding to a faulty input tributary, should be such that the status of the justification control digits is controlled so as to ensure that the AIS is within the tolerance specified for that tributary.

Note 1 – The bit rate of the AIS at the output of the multiplexer equipment or at the output of the demultiplexer equipment should be in accordance with the interface specifications.

Note 2 – The equivalent binary content of the AIS at 8448 kbit/s, 34 368 kbit/s and 139 264 kbit/s is nominally a continuous stream of 1s. The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio $1 \cdot 10^{-3}$. However a signal with all bits except the frame alignment signal in the 1 state, should not be mistaken for an AIS.

4.5.3 *Time requirements*

The fault detection and the application of the consequent actions given in §§ 4.5.2.2 to 4.5.2.7, including the detection of AIS, should be completed within a time limit of 1 ms.

TABLE 4/G.751

Fault conditions and consequent actions

Equipment part	Fault conditions (see § 4.5.1)	Consequent actions (see § 4.5.2)						
		Prompt maintenance alarm indication generated	Alarm indication on the 139 264-kbit/s signal to the remote multiplex equipment generated	Alarm indication on a 34 368-kbit/s signal to the remote multiplex equipment generated	AIS applied			
					To all the 16 tributaries at 8448 kbit/s at the output of the demultiplexer	To the 4 relevant tributaries at 8448 kbit/s at the output of the demultiplexer	To the composite signal at 139 264 kbit/s at the output of the multiplexer	To the relevant time slot of the composite signal
Multiplexer and demultiplexer	Loss of power supply	Yes			Yes, if practicable		Yes, if practicable	
Multiplexer only	Loss of incoming signal on a tributary	Yes						Yes
Demultiplexer only	Loss of incoming signal at 139 264 kbit/s	Yes	Yes		Yes			
	Loss of frame alignment on the 139 264-kbit/s signal	Yes	Yes		Yes			
	Alarm indication received from the remote multiplex equipment on the 139 264-kbit/s signal							
	Loss of frame alignment on a 34 368-kbit/s signal	Yes		Yes		Yes		
	Alarm indication received from the remote multiplex equipment on a 34 368-kbit/s signal							

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Recommendation G.752

CHARACTERISTICS OF DIGITAL MULTIPLEX EQUIPMENTS BASED ON A SECOND ORDER BIT RATE OF 6312 kbit/s AND USING POSITIVE JUSTIFICATION

(Geneva, 1976; amended at Geneva, 1980)

General

Characteristics of digital multiplex equipments above the third order are under study.

The CCITT,

considering

(a) that various third- and higher-order multiplex equipments exist due to the differing characteristics of networks and signal sources in those networks;

(b) that, although studies will continue with the aim of reducing the differences between various systems, the existing situation cannot be changed in the near future;

recommends the following

(1) when countries using 1544-kbit/s primary multiplex equipments, such as the PCM multiplex equipment according to Recommendation G.733 and second-order multiplex using 6312 kbit/s according to Recommendation G.743, are planning digital paths requiring interconnection at higher bit rates they should, when practical, utilize third-order bit rates of either 32 064 kbit/s or 44 736 kbit/s. The considerations behind the choices available to such Administrations are given in § (3) below;

(2) the characteristics of the third-order multiplex equipments using positive justification is given in § 1, below;

(3) in establishing recommendations for digital systems to facilitate the interconnection of digital networks, the requirements for directly encoding various signal sources must be considered. In addition, it is desirable that the recommendations for digital signals be established without unduly restricting the development of future national and international systems. It is also advisable that the rates recommended be limited to a reasonably small number. In cases where systems are operating according to different recommendations, interconnection will be feasible since digital techniques allow for efficient and economic conversion of signals from one bit rate to another.

Recognition of a basic set of bit rates and signal formats (a hierarchy) is therefore deemed necessary to facilitate interconnection and to provide guidance to the designers of future equipments. The choice of the basic signal structure should take into consideration the future connection of wideband analogue signals into the digital network. For these reasons recommendations for bit rates suitable for analogue source encoding (below approximately 100 Mbit/s) are fundamental and therefore should receive priority attention.

Figure 1/G.752 illustrates the basic multiplex arrangements recommended for Administrations using 1544-kbit/s primary multiplex equipment.

The bit rates of terrestrial systems should be a multiple of 1544 kbit/s. Whenever practicable, the bit rate should also be a multiple of 6312 kbit/s and either 32 064 or 44 736 kbit/s.

1 Third-order digital multiplex equipment based on second-order bit rate of 6312 kbit/s and using positive justification

1.1 *General*

The third-order digital multiplex equipment using positive justification described below, is intended for use on digital paths and between countries using 1544-kbit/s and 6312-kbit/s primary and secondary multiplex equipments.

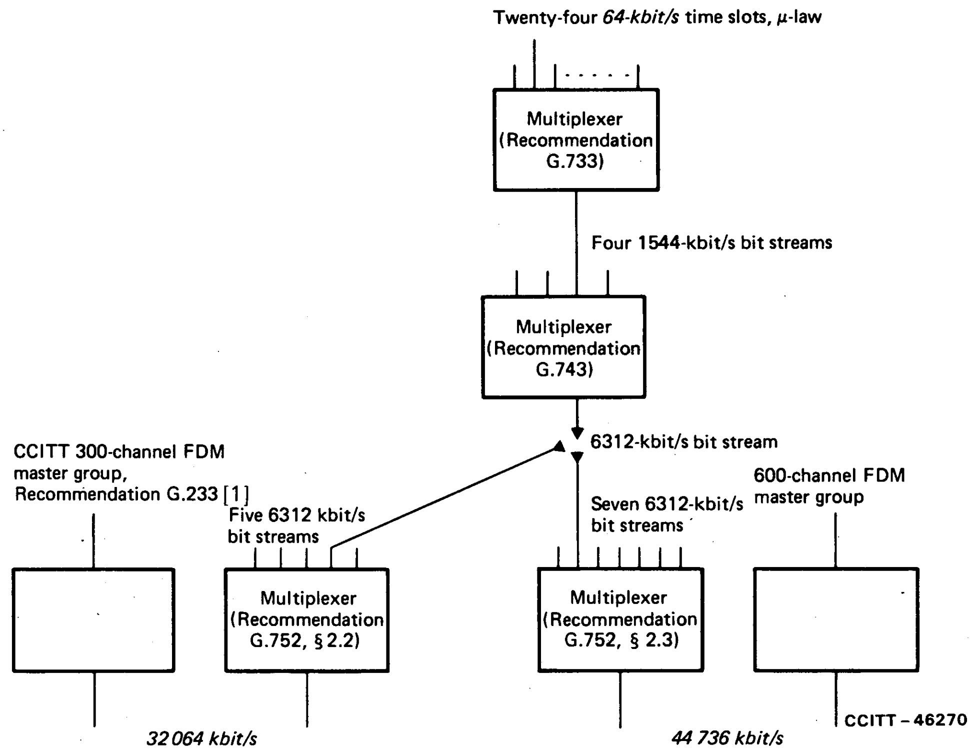


FIGURE 1/G.752

Basic multiplex arrangements for 1544-kbit/s derived networks

A bit rate of either 32 064 kbit/s or 44 736 kbit/s is recommended to allow for the efficient and economical coding of wideband signals in the networks of Administrations using primary systems according to Recommendations G.733 and G.743. For instance for a 300 voice-circuit mastergroup (Recommendation G.233 [1]) 32 064 kbit/s is appropriate, while for a 600 voice-circuit mastergroup 44 736 kbit/s coding is appropriate.

1.2 *Third-order digital multiplex equipment operating at 32 064 kbit/s*

1.2.1 *Bit rate*

The nominal bit rate should be 32 064 kbit/s. The tolerance on that rate should be ± 10 parts per million (ppm).

1.2.2 *Frame structure*

Table 1/G.752 gives:

– the tributary bit rate and the number of tributaries;
– the number of bits per frame;
– the bit numbering scheme;
– the bit assignment;
– the frame alignment signal.

1.2.3 *Loss and recovery of frame alignment and consequent action*

The frame alignment recovery time should not exceed 8 ms. The signal to be applied to the tributaries during the out-of-frame alignment time should be studied.

TABLE 1/G.752

32 064-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	6312
Number of tributaries	5
Frame structure	Bit number
	Set I
Bits for frame alignment signal (see Note 1)	1 to 5
Bits from tributaries	6 to 320
	Set II
C_{jn} (n = 1, 2, 3) for justification control signal (see Note 2)	1 to 3
Auxiliary bits (bits for additional information transmission) H_{jn} (n = 1, 2)	4 to 5
Bits from tributaries	6 to 320
	Set III
C_{2n} (n = 1, 2, 3) for justification control signal (see Note 2)	1 to 3
Auxiliary bits H_{2n} (n = 1, 2)	4 to 5
Bits from tributaries	6 to 320
	Set IV
C_{3n} (n = 1, 2, 3) for justification control signal (see Note 2)	1 to 3
Auxiliary bits H_{3n} (n = 1, 2)	4 to 5
Bits from tributaries	6 to 320
	Set V
C_{4n} (n = 1, 2, 3) for justification control signal (see Note 2)	1 to 3
Auxiliary bits H_{4n} (n = 1, 2)	4 to 5
Bits from tributaries	6 to 320
	Set VI
C_{5n} (n = 1, 2, 3) for justification control signal (see Note 2)	1 to 3
Auxiliary bits H_{5n} (n = 1, 2) (see Note 3)	4 to 5
Bits from tributaries	6 to 320
Frame length	1920 bits
Bits per tributary (including justification)	378 bits
Maximum justification rate per tributary	16 700 bit/s
Nominal justification ratio	0.036

Note 1 – The frame alignment signal is a 11010 pattern for the odd frame and a 00101 pattern for the even frame.
Note 2 – C_{jn} indicates the nth justification control bit of the jth tributary (j = 1 to 5).
Note 3 – H_{52} is used for transmitting failure information from the receive end to the transmit end.
Note 4 – The bit available for the justification of tributary j is the first slot of tributary j in Set (j + 1).

1.2.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 1/G.752).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

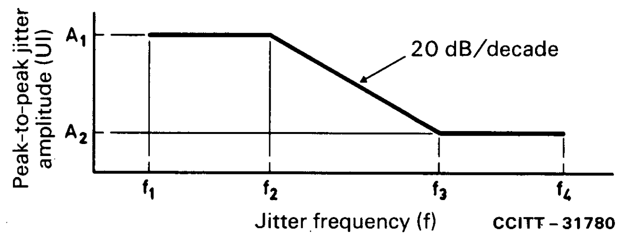
Table 1/G.752 gives the maximum justification rate per tributary and the nominal justification ratio.

1.2.5 *Jitter*

1.2.5.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 2/G.752. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length $2^{15} - 1$.

Note – The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.



Input	A_1 (UI)	A_2 (UI)	f_1 (Hz)	f_2 (kHz)	f_3 (kHz)	f_4 (kHz)
6312 kbit/s	1	0.05	60	1.6	32	160
32 064 kbit/s (provisional)	5	0.05	60	1.6	160	800

UI Unit interval

FIGURE 2/G.752

Lower limit of maximum tolerable input jitter

1.2.5.2 *Multiplex signal output jitter*

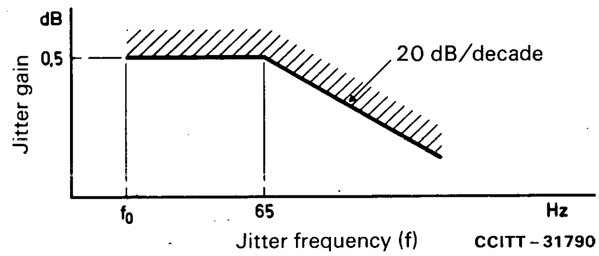
The jitter at the 32 064-kbit/s output of the multiplexer should not exceed 0.01 UI rms.

1.2.5.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

The peak-to-peak jitter at a tributary output of the demultiplexer with no jitter at the inputs should not exceed 0.2 UI.

1.2.5.4 *Demultiplexer jitter transfer characteristic*

A 6312 kbit/s signal, modulated by sinusoidal jitter, should be subject to a demultiplexer jitter transfer characteristic within the gain/frequency limits given in Figure 3/G.752.



Note – The frequency f_0 should be as low as possible taking into account the limitations of measuring equipment.

FIGURE 3/G.752

Demultiplexer transfer characteristic

1.2.6 *Digital interface*

The digital interfaces at 6312 kbit/s and 32 064 kbit/s should be in accordance with Recommendation G.703.

1.2.7 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

1.2.8 *Service digits*

The service digits are reserved for national use.

1.3 *Third-order digital multiplex operating at 44 736 kbit/s*

1.3.1 *Bit rate*

The nominal bit rate should be 44 736 kbit/s.

The tolerance on that rate should be ± 20 parts per million (ppm).

1.3.2 *Frame structure* (see Table 2/G.752)

1.3.3 *Loss and recovery of frame and multiframe alignment and consequent action*

The frame alignment recovery time should not exceed 2.5 ms. The signal to be applied to the tributaries during the out-of-frame alignment time should be studied.

Once frame alignment is established, multiframe alignment should be recovered in less than 250 µs.

1.3.4 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended.

The justification control signal should be distributed and use the C_{jn}-bits (n = 1, 2, 3, see Table 2/G.752).

Positive justification should be indicated by the signal 111, no justification by the signal 000. Majority decision is recommended.

Table 2/G.752 gives the maximum justification rate per tributary and the nominal justification ratio.

TABLE 2/G.752

44 736-kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	6312
Number of tributaries	7
Frame structure (see Note 1)	Bit number
Bit for multiframe alignment signal (M_j) (see Note 1) Bits from tributaries	*Set I* 1 2 to 85
1st bit for frame alignment signal (F_{11}) (see Note 2) Bits from tributaries	*Set II* 1 2 to 85
1st bit for justification control signal (C_{j1}) Bits from tributaries	*Set III* 1 2 to 85
2nd bit for frame alignment signal (F_0) Bits from tributaries	*Set IV* 1 2 to 85
2nd bit for justification control signal (C_{j2}) Bits from tributaries	*Set V* 1 2 to 85
3rd bit for frame alignment signal (F_0) Bits from tributaries	*Set VI* 1 2 to 85
3rd bit for justification control signal (C_{j3}) Bits from tributaries	*Set VII* 1 2 to 85
4th bit for frame alignment signal (F_{12}) Bits from tributaries (see Note 3)	*Set VIII* 1 2 to 85
Frame length Multiframe length Bits per tributary per multiframe (including justification) Maximum justification rate per tributary Nominal justification ratio	680 bits 4760 bits 672 bits 9398 bit/s 0.390

Note 1 – This frame is repeated 7 times to form a multiframe with frames designated j = 1, 2, 3, 4, 5, 6, 7. The multiframe alignment signal is an XXPP010 pattern where X is a bit assigned to service function, and P is the parity bit for the preceding multiframe (i.e. from M_1 to M_7). P = 1 if the number of marks in all bits the preceding multiframe is odd, P = 0 if the number of marks in all bits in the preceding multiframe is even. Note that the two X bits are identical in any multiframe, as are the two P bits.

Note 2 – The frame alignment signal is $F_0 = 0$ and $F_{11} = F_{12} = 1$.

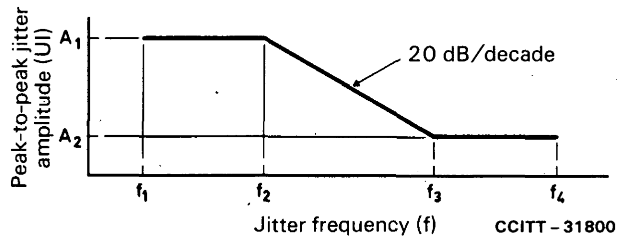
Note 3 – The bit available for the justification of tributary *j* is the first slot of tributary *j* following F_{12} in the *j*th frame.

1.3.5 *Jitter*

1.3.5.1 *Specifications at the input ports*

The digital signal presented at the input ports shall be as defined in Recommendation G.703 modified by the transmission characteristic of the interconnecting cable. The input ports shall be able to tolerate a digital signal with these electrical characteristics but modified by sinusoidal jitter up to the limits specified by the amplitude frequency relationship in Figure 4/G.752. The equivalent binary content of the signal, with jitter modulation, applied to the inputs shall be a pseudo-random bit sequence of length $2^{15} - 1$.

Note – The signal with jitter modulation applied to the demultiplexer input shall contain the bits necessary for framing and justification in addition to information bits.



Input	A_1 (UI)	A_2 (UI)	f_1 (Hz)	f_2 (kHz)	f_3 (kHz)	f_4 (kHz)
6312 kbit/s	2	0.05	10	0.6	24	120
44 736 kbit/s	14	0.05	10	3.2	900	4500

UI Unit interval

FIGURE 4/G.752

Lower limit of maximum tolerable input jitter

1.3.5.2 *Multiplex signal output jitter*

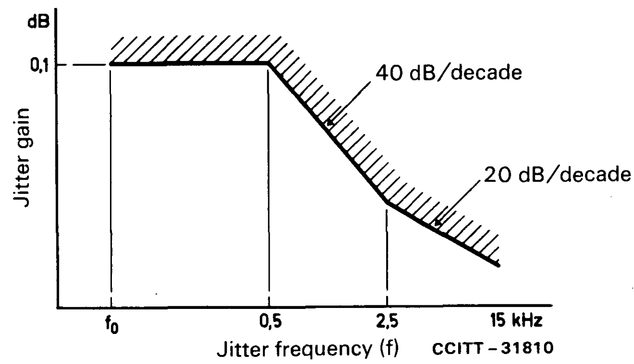
The jitter at the 44 736-kbit/s multiplexer output should not exceed 0.01 UI rms.

1.3.5.3 *Demultiplexer output jitter with no multiplexer or demultiplexer input jitter*

With no jitter at the input to the multiplexer and demultiplexer, the jitter at the demultiplexer output should not exceed 1/5 UI peak-peak.

1.3.5.4 *Demultiplexer jitter transfer characteristic*

The gain of the jitter transfer characteristic should not exceed the limits given in Figure 5/G.752.



Note – The frequency f_0 should be as low as possible taking into account the limitations of measuring equipment.

FIGURE 5/G.752

Demultiplexer transfer characteristic

1.3.6 *Digital interfaces*

The digital interfaces at 6312 kbit/s and 44 736 kbit/s should be in accordance with Recommendation G.703.

1.3.7 *Timing signal*

If it is economically feasible, it may be desirable to be able to derive the multiplexer timing signal from an external source as well as from an internal source.

1.3.8 *Service digits*

The service digits are reserved for national use.

Reference

[1] CCITT Recommendation *Recommendations concerning translating equipments*, Vol. III, Fascicle III.2, Rec. G.233.

Recommendation G.753

THIRD ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 34 368 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1980)

1 General

The third order digital multiplex system with positive/zero/negative pulse justification as given below is intended for digital connection between countries using second order digital systems at 8448 kbit/s with the same type of justification.

2 Bit rate

The nominal bit rate should be 34 368 kbit/s. The tolerance on that rate should not be more than $\pm 2 \times 10^{-5}$.

3 Frame structure

Table 1/G.753 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

TABLE 1/G.753

34 368-kbit/s multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	8448
Number of tributaries	4
Frame structure	Bit number
	Set I
Frame alignment signal (111110100000)	1 to 12
Bits from the secondary tributaries	13 to 716
	Set II
Justification control bits (C_{j1})	1 to 4
Bits for service functions	5 to 8
Justification control bits (C_{j2})	9 to 12
Bits from the secondary tributaries	13 to 716
	Set III
Justification control bits (C_{j3})	1 to 4
Bits reserved for national use	5 to 8
Bits from tributaries available for negative justification	9 to 12
Bits from tributaries available for positive justification	13 to 16
Bits from the tributaries	17 to 716
Frame length	2148 bits
Frame duration	62.5 µs
Bits per tributary	528
Maximum justification rate per tributary	16 kbit/s

Note – C_{jn} – indicates the *n*th justification control pulse of the *j*th tributary.

4 Loss and recovery of frame alignment and consequent actions

The frame alignment system should be adaptive to the error ratio in the line link. Until frame alignment is restored the frame alignment system should retain its position. A new search for the frame alignment signal should be undertaken when three or more consecutive frame alignment signals have been incorrectly received in their positions.

Frame alignment is considered to have been recovered when more than two consecutive frame alignment signals have been correctly received in their predicted positions.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive-negative justification with two-command control are recommended. The justification control signal should be distributed and use C_{jn}-bits ($n = 1, 2, 3$ see Table 1/G.753). Correction of one error in a command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000, transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame.

Digit time slots 9, 10, 11, 12 (Set III) are used for information carrying bits (for negative justification), and digit time slots 13, 14, 15, 16 in Set III when it is necessary are used for no information carrying bits (for positive justification) for the tributaries 1, 2, 3, 4.

Table 1/G.753 gives maximum justification rate per tributary.

6 Jitter

The amount of jitter that should be accepted at the inputs of the demultiplexer and multiplexer, and should be at the output of the multiplexer is under study.

7 Digital interface

The interface at the nominal bit rate 34 368 kbit/s is under study.

8 Timing signal

The clock should be able to be controlled by an external source.

9 Service digits

Some spare bits (5 to 8 in Set III) are available for service functions for national and international use.

The bit allocation between services is under study.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of the incoming signal at 8448 kbit/s at the input of the multiplexer.

Note – When using separate circuits for the digital signal and the timing signal, loss of either or both of them should constitute loss of the incoming signal.

10.1.3 Loss of the incoming signal at 34 368 kbit/s at the input of the demultiplexer.

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 34 368-kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

After detecting a fault condition, appropriate actions should be taken as specified in Table 2/G.753. The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that the performance is below acceptable standards and maintenance attention is required locally. When detecting the Alarm Indication Signal (AIS) at the 34 368-kbit/s input of the demultiplexer the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited (see Note 1 below).

Note – The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 8 of Set II at the 34 368-kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all four outputs of the 8448-kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 34 368-kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 34 368-kbit/s signal at the multiplexer output corresponding to the relevant 8448-kbit/s tributary.

Note 1 – The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 – The equivalent binary content of the AIS at 8448 kbit/s and 34 368 kbit/s is a continuous stream of binary 1s.

TABLE 2/G.753

Fault conditions and consequent actions

Equipment part	Fault conditions (see § 10.1)	Consequent actions (see § 10.2)				
		Prompt maintenance alarm indication generated	Alarm indication to the remote multiplexer generated	AIS applied		
				To all tributaries	To the composite signal	To the relevant time slots of the composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	
Multiplexer only	Loss of incoming signal on a tributary	Yes				Yes
Demultiplexer only	Loss of incoming signal at 34 368 kbit/s	Yes	Yes	Yes		
	Loss of frame alignment	Yes	Yes	Yes		
	AIS received from the remote multiplexer					

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

Recommendation G.754

FOURTH ORDER DIGITAL MULTIPLEX EQUIPMENT OPERATING AT 139 264 kbit/s AND USING POSITIVE/ZERO/NEGATIVE JUSTIFICATION

(Geneva, 1980)

1 General

The fourth order digital multiplex system with positive/zero/negative pulse justification as given below is intended for use on digital connection between countries using third order digital systems at 34 368 kbit/s with the same type of justification.

2 Bit rate

The nominal bit rate should be 139 264 kbit/s. The tolerance on that rate should not be more than $\pm 1.5 \times 10^{-5}$.

3 Frame structure

Table 1/G.754 gives:

- the tributary bit rate and the number of tributaries;
- the number of bits per frame;
- the bit numbering scheme;
- the bit assignment;
- the bunched frame alignment signal.

TABLE 1/G.754

139 264-kbit/s multiplexing frame structure using positive/zero/negative justification

Tributary bit rate (kbit/s)	34368
Number of tributaries	4
Frame structure	Bit number
	Set I
Frame alignment signal	1 to 10
Bits for service functions	11 to 12
Bits from tributaries	13 to 544
	Set II
Justification control bits (C_{j1})	1 to 4
Bits from tributaries	5 to 544
	Set III
Justification control bits (C_{j2})	1 to 4
Bits from tributaries	5 to 544
	Set IV
Justification control bits (C_{j3})	1 to 4
Bits from tributaries available for negative justification	5 to 8
Bits from tributaries available for positive justification	9 to 12
Bits from tributaries	13 to 544
Frame length	2176 bits
Frame duration	15.625 μs
Bits per tributary	537
Maximum justification rate per tributary	64 kbit/s

Note – C_{jn} – indicated the *n*th justification control bit of the *j*th tributary.

4 Loss and recovery of frame alignment and consequent action

The frame alignment system should be adaptive to the error rate in the line link. Until frame alignment is restored the frame alignment system should retain its position. A new search for the frame alignment signal should be undertaken when three and more consecutive frame alignment signals have been incorrectly received in their position.

Frame alignment is considered to have been recovered when more than two consecutive frame alignment signals have been correctly received in their predicted positions.

5 Multiplexing method

Cyclic bit interleaving in the tributary numbering order and positive-negative justification with two-command control are recommended. The justification control signal should be distributed and use C_{jn}-bits ($n = 1, 2, 3$ see Table 1/G.754). Correction of one symbol error in a command is possible.

Positive justification should be indicated by the signal 111, transmitted in each of two consecutive frames; negative justification should be indicated by the signal 000, transmitted in each of two consecutive frames, and no justification by the signal 111 in one frame followed by 000 in the next frame.

Digit time slots 5, 6, 7, 8 (Set IV) are used for information carrying bits (for negative justification), and digit time slots 9, 10, 11, 12 in Set IV, when it is necessary, are used for no information carrying bits (for positive justification) for the tributaries 1, 2, 3, 4.

Table 1/G.754 gives maximum justification rate per each third order tributary.

6 Jitter

The amount of jitter that should be accepted at the inputs of the demultiplexer and multiplexer and should be at the output of the demultiplexer is under study.

7 Digital interface

The interface at the nominal bit rates 34 368 kbit/s and 139 264 kbit/s is under study.

8 Timing signal

The clock should be able to be controlled by an external source.

9 Service functions

Some spare bits (11 and 12 in Set I) are available for service functions for national and international use.

The bit allocation between service is under study.

10 Fault conditions and consequent actions

10.1 The digital multiplex equipment should detect the following fault conditions:

10.1.1 Failure of power supply.

10.1.2 Loss of the incoming signal at 34 368 kbit/s at the input of the multiplexer.

10.1.3 Loss of the incoming signal at 139 264 kbit/s at the input of the demultiplexer.

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

10.1.4 Loss of frame alignment.

10.1.5 Alarm indication received from the remote multiplex equipment at the 139 264-kbit/s input of the demultiplexer (see § 10.2.2 below).

10.2 *Consequent actions*

After detection of a fault condition appropriate actions should be taken as specified in the Table 2/G.754 . The consequent actions are as follows:

10.2.1 Prompt maintenance alarm indication generated to signify that the performance standards and maintenance attention is required locally. When detecting the Alarm Indication Signal (AIS) at the 139 264-kbit/s input of the demultiplexer the prompt maintenance alarm indication associated with loss of frame alignment should be inhibited (see Note 1 below).

Note – The location and provision of any visual and/or audible alarm activated by this prompt maintenance alarm indication is left to the discretion of each Administration.

10.2.2 Alarm indication to the remote multiplex equipment generated by changing from the state 0 to the state 1 bit 12 of set I at the 139 264-kbit/s output of the multiplexer.

10.2.3 AIS (see Note 2 below) applied to all the four outputs of the 34 368-kbit/s tributary outputs from the demultiplexer.

10.2.4 AIS (see Note 2 below) applied to the 139 264-kbit/s output of the multiplexer.

10.2.5 AIS (see Note 2 below) applied to the time slots of the 139 264-kbit/s signal at the multiplexer output corresponding to the relevant 34 368-kbit/s tributary.

Note 1 – The bit rate of the AIS at the output of the corresponding demultiplexer should be as specified for the tributaries. The method of achieving this is under study.

Note 2 – The equivalent binary content of the AIS at 34 368 kbit/s and 139 264 kbit/s is a continuous stream of binary 1s.

TABLE 2/G.754

Fault conditions and consequent actions

Equipment part	Fault conditions (see § 10.1)	Consequent actions (see § 10.2)				
		Prompt maintenance alarm indication generated	Alarm indication to the remote multiplexer generated	AIS applied		
				To all tributaries	To the composite signal	To the relevant time slots of the composite signal
Multiplexer and demultiplexer	Failure of power supply	Yes	Yes, if practicable	Yes, if practicable	Yes, if practicable	
Multiplexer only	Loss of incoming signal on a tributary	Yes				Yes
Demultiplexer only	Loss of incoming signal at 139 264 kbit/s	Yes	Yes	Yes		
	Loss of frame alignment	Yes	Yes	Yes		
	AIS received from the remote multiplexer					

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

7.9 Other terminal equipments

Recommendation G.791

GENERAL CONSIDERATIONS ON TRANSMULTIPLEXING EQUIPMENTS

(Geneva, 1980)

The CCITT,

considering

the advantages offered in some cases by direct through-connection (without voice-frequency interfaces) from FDM signals to TDM signals and vice versa,

recommends in such cases

(1) the use of the transmultiplexing equipment described in Definition 3028 of Recommendation G.702;

(2) Recommendation G.792 which contains the characteristics common to all transmultiplexing equipment;

(3) Recommendation G.793 which concerns 60-channel transmultiplexers providing 2048-kbit/s signals and using A-law encoding;

(4) future Recommendation G.794 which will concern 24-channel transmultiplexers providing 1544-kbit/s signals and using μ-law encoding;

(5) Recommendation G.79x which may appear in the future for other kinds of transmultiplexers.

1 Complementary definitions

1.1 type P transmultiplexer (TMUX-P)

A transmultiplexing equipment in which the analogue interface is made up of one or more groups.

1.2 type S transmultiplexer (TMUX-S)

A transmultiplexing equipment in which the analogue interface is made up of one or more supergroups.

1.3 hierarchical transmultiplexer

A transmultiplexer in which the digital interfaces satisfy the provisions of Recommendation G.703 and the analogue interfaces those of Recommendation G.233 [1].

1.4 transmultiplexer channel

A frequency band of 4000 Hz on the analogue side, corresponding to a bit rate of 64 kbit/s on the digital side, which permits the transmission of a signal limited to the telephone band 300-3400 Hz. Access may be gained to a given channel:

- either at the level of the time-slot associated with the relevant channel of the TDM signal;
- or at the level of the frequency band (f_p, $f_p \pm 4000$ Hz) of the FDM signal, f_p being the virtual carrier frequency associated with the channel concerned. The + sign corresponds to the case of the base supergroup, the − sign to the case of the base group.

Note – Correspondence between out-of-band signalling on the analogue side and channel associated signalling on the digital side will be covered in the Recommendations specific to the various transmultiplexers.

Reference

[1] CCITT Recommendation *Recommendations concerning translating equipments*, Vol. III, Fascicle III.2, Rec. G.233.

CHARACTERISTICS COMMON TO ALL TRANSMULTIPLEXING EQUIPMENTS

(Geneva, 1980)

The CCITT,

recommends

that the characteristics below be respected by all the transmultiplexing equipments defined in Recommendation G.791.

1 Coding law

Transmultiplexers should satisfy Recommendation G.711, § 3.

2 Sampling rate of PCM channels

The sampling rate of PCM channels is 8000 Hz $\pm$ 50 $\cdot$ 10^{-6} according to Recommendation G.711, § 2.

3 Amplitude limitation of PCM channels

In accordance with Recommendation G.711, § 4, the theoretical load capacity of PCM channel is +3.14 dBm0 for the A-law and +3.17 dBm0 for the μ-law.

4 Accuracy of the analogue virtual carriers

The analogue virtual carriers should satisfy the Recommendation cited in [1].

5 Characteristics of the pilots

The pilots of the analogue groups should be transmitted in conformity with the Recommendation cited in [2]; the nominal characteristics (level, frequencies) should conform to those given in [3]; and the tolerances should meet those indicated in [4].

6 Saturation level at the input of the analogue group

The transmultiplexer should be able to accept at their analogue input levels corresponding to the equivalent peak powers defined in Table 3/G.223 [5] (for example, +19 dBm0 for a group and +20.8 dBm0 for a supergroup).

7 Regulation

A distinction must be made depending on whether analogue group regulation is included or not in the transmultiplexer. If so, the transmultiplexer must meet the conditions of the Recommendation cited in [2]. If not, it has been proposed that the transmultiplexer should function taking into account input level variations of ± 2 dB. This point needs further studies.

Note – For the sake of the convenience and precision of the measurements, it is desirable that the regulation, when included in the transmultiplexer, can be blocked with a gain equal to unity. The specifications in §§ 9 to 26 below assume such blocking.

8 Methods of measuring quality in the audio band

The various possible methods of measuring quality characteristics in the audio band are indicated in Figure 1/G.792.

The method to be used in preference is method C (measurement of the multiplexed analogue signal, the digital ports being looped). When method C cannot be used (e.g., for measurement of the signal/total distortion signal as a function of the level), method D should be used (measurement at the level of the multiplexed digital signal, the analogue ports being looped). However, as method D requires digital signal generators and analysers, which certain Administrations do not yet possess, method A can be used provisionally [looping of the digital ports, use of the terminals of auxiliary analogue channels (and possibly group modulators), assumption of the additivity of impairments and deduction of the impairments at the terminals of the channels (and possibly modulators) previously measured].

Methods B and E are given for information but are not recommended.

Method F corresponds in fact to four possible methods, depending on whether the emission of the test signal and its detection take place on the analogue side or the digital side.

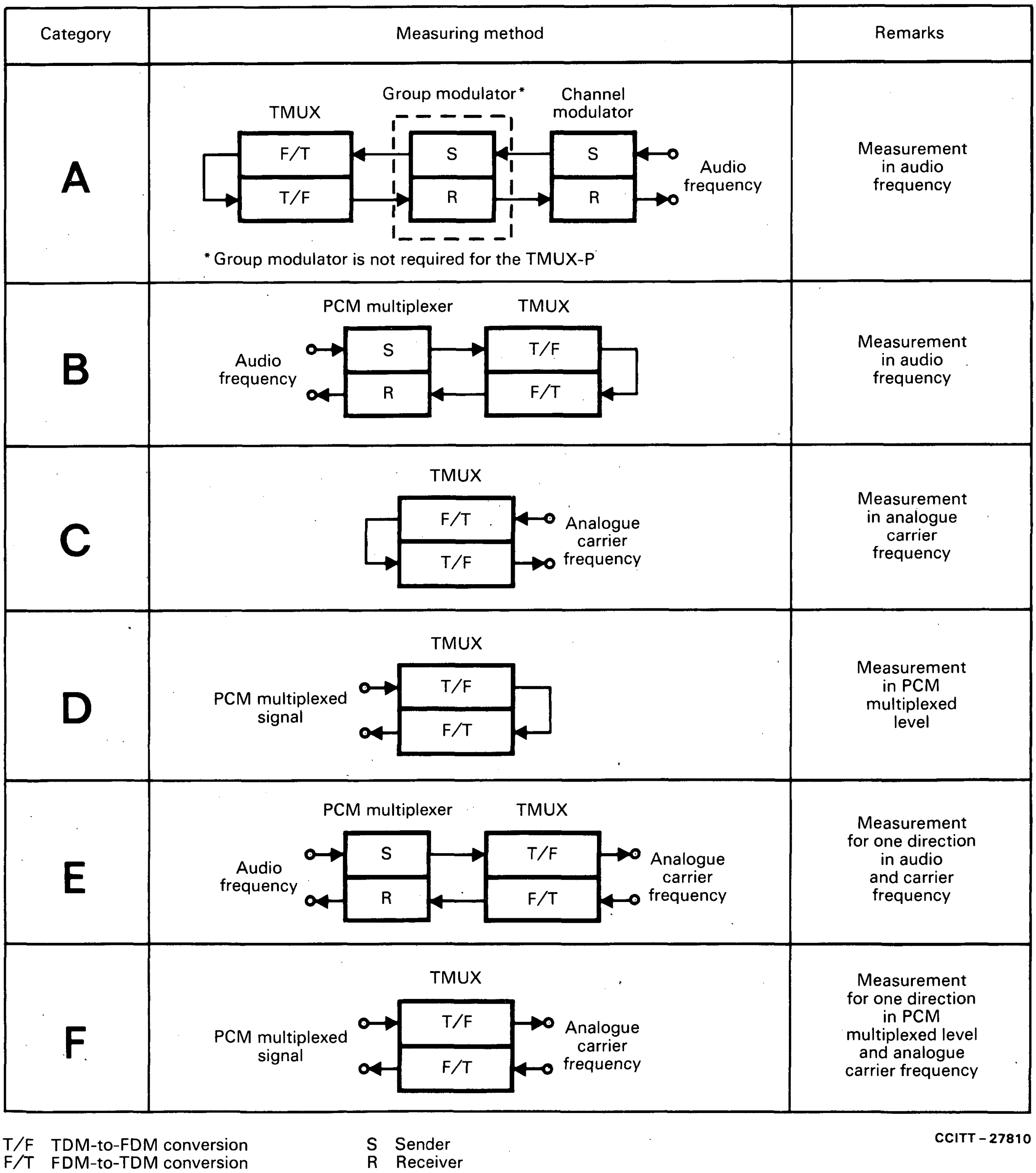


FIGURE 1/G.792

Block diagrams of measuring methods for transmultiplexers

9 Attenuation distortion in the voice-frequency band as a function of frequency

The measuring method is method C.

The variation of the attenuation of each channel of a transmultiplexer as a function of frequency must remain within the limits of the mask in Figure 2/G.792. The level of emission is 0 dBm0; the reference frequency is 800 Hz.

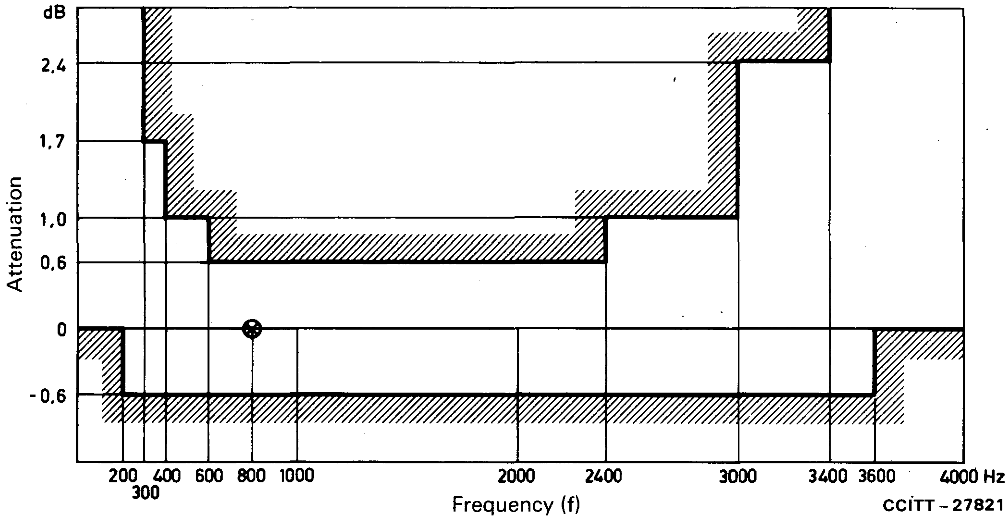


FIGURE 2/G.792

Attenuation distortion mask as a function of the frequency to be observed for all channels of a transmultiplexer

10 Group delay

10.1 *Absolute value of the group delay*

The measuring method is method C.

The absolute value of group delay defined as the minimum value of group delay in the speech band 300-3400 Hz should remain less than 3 ms for all the channels of a transmultiplexer.

10.2 *Group-delay distortion*

The measuring method is method C.

The group-delay distortion should not exceed the limits of the mask in Figure 3/G.792.

The minimum group delay is taken as a reference; the power level at the input is 0 dBm0.

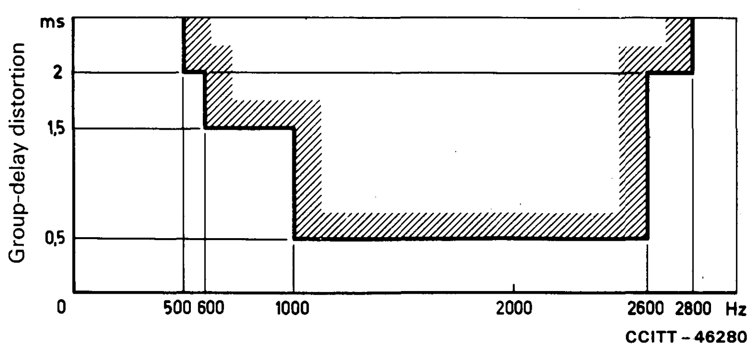


FIGURE 3/G.792

Mask of group-delay distortion as a function of frequency

11 Noise

11.1 *Idle channel noise, with all channels idle*

The measuring method is method D.

When a PCM signal corresponding to amplitude 0 for the μ-law and the number 1 for the A-law in all channels of the transmultiplexer is applied to the digital input of the transmultiplexer, the psophometric noise measured over any channel at the digital output should not exceed −65 dBm0p. The measurement is conducted in the presence of pilots.

11.2 *Idle channel noise, with all channels loaded except the one measured*

The measuring method is method C. In this case an intermodulation measuring set-up using the white noise method is employed, as described in the Recommendation cited in [6].

The level of emission of the noise signal being equal to the conventional load of the FDM signal considered (the Recommendation cited in [7]: 3.3 dBm0 for the group, 6.1 dBm0 for the supergroup), the noise measured in any given measuring slot should not exceed −62.5 dBm0p (i.e., −60 dBm0 in a 3100 Hz band).

The centre frequencies of the specified measuring slots (CCITT Recommendation G.230 [8] and CCIR Recommendation 482 [9]) applicable to the transmultiplexers are:

- for the base group: 70 and 98 kHz
- for the base supergroup: 394 and 534 kHz

This measurement is carried out without emitting pilots or out-of-band signalling.

11.3 *Single frequency noise outside the band 300-3400 Hz*

This point needs further study.

11.4 *Idle noise in the PCM – FDM direction all channels idle*

The measuring method is method F. A PCM signal, amplitude 0 for the μ-law and 1 for the A-law is applied at the digital input of the transmultiplexer in all channels. The power of the noise measured at the analogue output in any channel must be less than −70 dBm0p.

Note – White noise is assumed, and to take account of the psophometric weighting, the measurement can be made in a band of 1740 Hz, centred on the odd multiples of 2 kHz. The measurement may be difficult in certain channels due to the presence of pilots.

12 Intermodulation

The measuring method is method C.

If two sine-wave signals of different frequencies f_1 and f_2 belonging to the band 300-3400 Hz of the channel considered, having no harmonic relation and of equivalent levels in the −4 to −21 dBm0 range, are applied simultaneously to the analogue ports of the transmultiplexer, there should be no intermodulation product of the type $2f_1 - f_2$ of a level higher than −35 dB with respect to the level of one of the two input signals.

13 Total distortion including quantizing distortion

The measuring method is method D (or provisionally method A).

If method D is used, the test signal is generated digitally and is therefore affected by theoretical quantizing distortion. A new mask should therefore be defined, obtained by addition in power of the distortion deduced from the masks defined below for transmultiplexers, and the theoretical quantizing distortion.

A choice between the two following methods is recommended:

Method 1

The signal-to-total distortion ratio measured according to method 1 described in § 9 of Recommendation G.712 should respect the mask of Figure 4/G.792. The mask is to be complied with by all channels of the transmultiplexer.

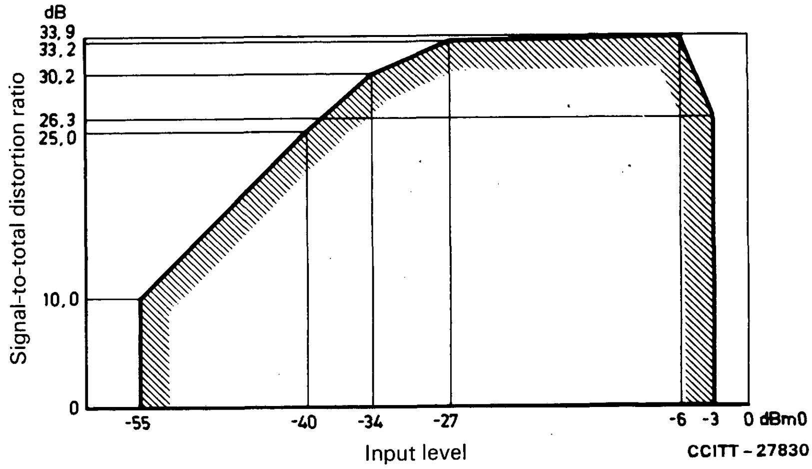


FIGURE 4/G.792

Signal-to-total distortion ratio as a function of the input level according to method 1 (Recommendation G.712, § 9)

Method 2

With a sine-wave signal at a frequency between 700 and 1100 Hz or 350 and 550 Hz (e.g. 420 ± 20 Hz) (except for submultiples of 8 kHz) being applied in the channel concerned at the digital input of the transmultiplexer, the ratio of signal-to-total distortion power, measured with appropriate noise weighting (see the Recommendation cited in [10]), should be below the limits of the mask represented in Figure 5/G.792. The mask is to be complied with by all the channels of the transmultiplexer.

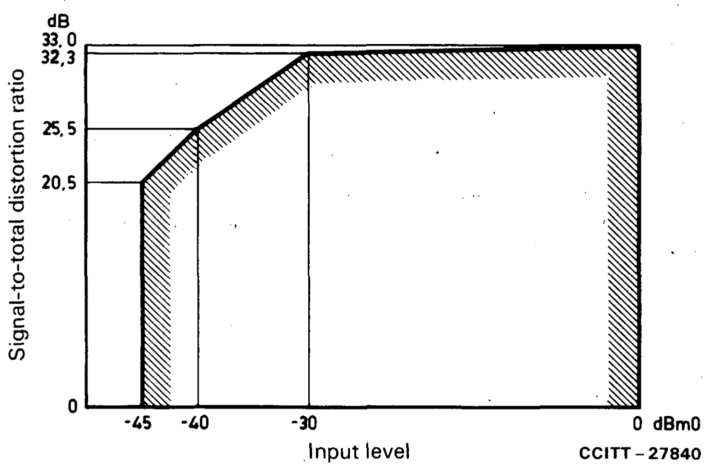


FIGURE 5/G.792

Signal-to-total distortion ratio as a function of the input level according to method 2 (Recommendation G.712, § 9)

14 In-band spurious signals

The measuring method is method C.

The transmultiplexers must meet the provisions of Recommendation G.712, § 10.

15 Variation of gain with the input level

The measuring method is method C, the pilots being present at the analogue input.

With a sine-wave signal at a frequency between 700 and 1100 Hz (except for sub-multiples of 8 kHz) and a level between −55 and +3 dBm0 being applied in the channel concerned at the analogue input of the transmultiplexer, the variation of gain with respect to its value for an input level of −10 dBm0 should remain between the limits of the mask shown in Figure 6/G.792. The mask is to be complied with by all channels of a transmultiplexer, according to the value for $S = -10$ dBm0.

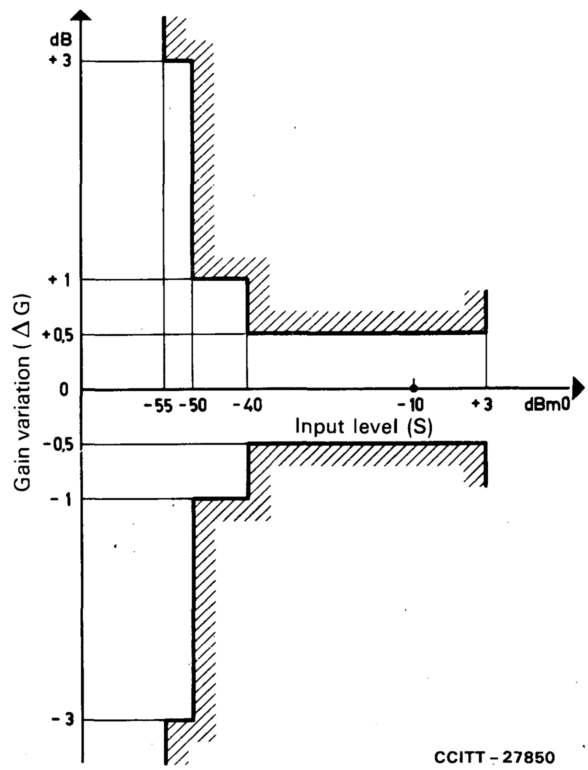


FIGURE 6/G.792

Variation in gain Δ G as a function of input level S, Method 2 in Recommendation G.712, § 11 (sinusoidal test signal)

16 Crosstalk

16.1 *Intelligible crosstalk*

Measuring method C or D.

The crosstalk ratio, measured according to method C between any pair of channels for any frequency between 700 and 1100 Hz (except for the submultiples of 8 kHz) and of level 0 dBm0, should be greater than 62 dB.

When measuring method D is used, the crosstalk ratio should be greater than 65 dB.

16.2 *Unintelligible crosstalk*

Measuring method D.

When a conventional telephone signal according to Recommendation G.227 [11], level 0 dBm0, is applied at the digital input of any channel, the level of crosstalk measured at the digital output in any other channel should not exceed −60 dBm0p.

17 Go-to-return crosstalk

Measuring method F, and the PCM signal corresponding to amplitude 0 for the μ-law and amplitude 1 for the A-law is applied at the digital input of all the channels.

When in any channel a sine-wave signal at a frequency between 300 and 3400 Hz and level 0 dBm0 is applied at the analogue input, the near-end crosstalk ratio between this channel and the return channel associated with it should be greater than 60 dB.

18 Variation of the equivalent of the channels within the FDM assembly with respect to the equivalent of the pilot channel within this assembly

Measuring method C.

When there is an emission at the analogue input of the transmultiplexer in any channel of a sine-wave (frequency 800 Hz and level 0 dBm0), the level measured at the analogue output of the transmultiplexer should be within ± 1 dB of the level measured in the channel of the pilot of the FDM assembly considered.

19 Adjustment of the relation between the coding law and the analogue level

Measuring method F.

To measure the correspondence between the coding laws and the analogue levels, the sequence of character signals from Table 5/G.711 for the A-law and from Table 6/G.711 for the μ-law may be applied periodically at the digital input of the transmultiplexer: the signal at the analogue output of the transmultiplexer should correspond to a sine-wave signal of frequency 1 kHz in the corresponding channel at a level between −0.5 and +0.5 dBm0.

To check the load capacity of the PCM coder contained in the transmultiplexer, a sine-wave signal at a frequency of 1000 ± 20 Hz (excluding any submultiple of the sampling frequency) can be applied for any channel at the analogue input of the transmultiplexer. Initially the level of this signal is considerably below the load capacity, then it is raised gradually. Note is taken of the input level at which the character signal corresponding to the extreme quantization interval for positive and negative amplitudes first appears at the digital output in the channel considered. The load capacity is then taken to be equal to this input level, increased by 0.3 dB. The values obtained for the various channels should be between 2.64 and 3.64 dBm0 for the A-law and between 2.67 and 3.67 dBm0 for the μ-law.

Note – The value of 1 kHz has been chosen to be in agreement with the present version of Recommendation G.711 and G.712. If, as a result of further studies, a frequency of 800 Hz has to be considered in the two above-mentioned Recommendations, this will have to be taken into account in the present Recommendation.

20 Carrier leak at the analogue ports

Measuring method C, the analogue input of the transmultiplexer being looped to its nominal impedance.

The transmultiplexers should meet the provisions of the Recommendation cited in [12].

21 Protection against out-of-band signals at the analogue ports

21.1 *Out-of-band spurious signals at the analogue output*

Measuring method C or F. The ratio between the wanted components and the various unwanted components defined in the Recommendation cited in [13] should be 70 dB for intelligible or unintelligible crosstalk towards the adjacent FDM assemblies. This ratio should be raised to 80 dB in the band of each adjacent assembly which corresponds to the band (f_1 + 12 kHz, f_2 − 12 kHz) of the base assembly, f_1 and f_2 being the extreme frequencies of the base FDM assembly considered.

21.2 *Crosstalk due to out-of-band signals at the analogue input*

Measuring method C or F. The ratio between the wanted components and the various unwanted components defined in the Recommendation cited in [13] should be 70 dB for intelligible or unintelligible crosstalk from the adjacent FDM assemblies.

22 Protection and suppression of pilots

Measuring method F.

The transmultiplexers should meet the provisions of the Recommendation cited in [14].

23 Protection and suppression of out-of-band signalling

23.1 *Protection of out-of-band signalling*

Measuring method F.

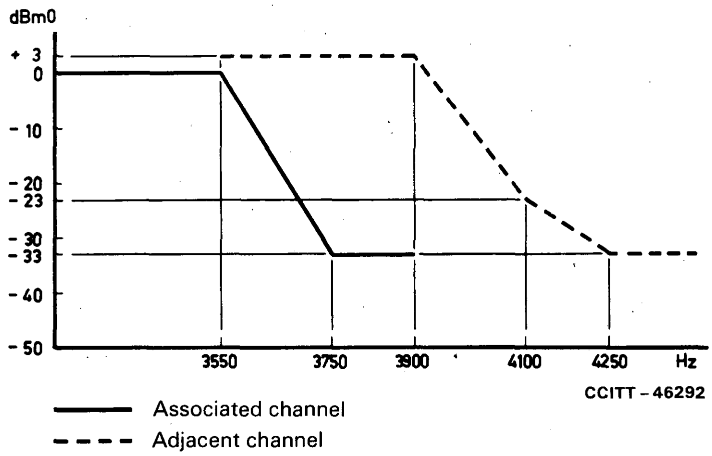
When a transmultiplexer is capable of emitting out-of-band signalling waves at frequency 3825 Hz, it should meet the provisions of Recommendation Q.414 [15], Figure 6/Q.414 being replaced by Figure 7/G.792. The measuring method associated with the latter figure is recalled in Note 2.

Note 1 – With a view to harmonization with the clauses of Recommendation G.232 [16], further study of these requirements may be necessary.

Note 2 – The signalling channel must be protected at the sending end against disturbance from the associated and the adjacent channel.

When a sine-wave at 0 dBm0 level is applied to the digital input of the associated channel, the level measured at the analogue output of the transmultiplexer must not exceed the levels shown in Figure 7/G.792.

When a sine-wave of frequency f is applied to the digital input of the adjacent channel, it produces two signals that appear on the frequency scale of Figure 7/G.792 as having the frequencies $(4000 + f)$ and $(4000 - f)$. The level of the $(4000 + f)$ signal measured at the analogue output of the transmultiplexer shall not be higher than –33 dBm0, when the sine-wave with frequency f is applied to the digital input of the adjacent channel at a level shown in Figure 7/G.792 for the frequency of $(4000 + f)$. The level of the $(4000 - f)$ signal, measured at the analogue output of the transmultiplexer, shall not be higher than –33 dBm0, when the sine-wave with frequency f is applied to the digital input of the adjacent channel at any level below the value shown in Figure 7/G.792 for the frequency $(4000 - f)$.



Note – The frequency of the virtual carrier of the associated speech channel is the origin of the frequency scale (zero frequency).

FIGURE 7/G.792

Protection of the signalling channel at the sending end

23.2 *Disturbance of telephone channels by out-of-band signalling*

The measuring method is method D.

Channel noise should not exceed –65 dBm0p in any channel:

- in the presence of all signalling waves (including the call channel) if low-level (–20 dBm0) out-band signalling waves are used;
- in the presence of signalling waves emitted in any channel (including the call channel) in a burst-mode at a rate of 10 Hz if high-level (–5 dBm0) out-of-band signalling waves are used.

Note – Moreover, the following design objectives must be taken into account:

– theoretical noise below −71 dBm0p in the call channel;

– theoretical noise below −76 dBm0p in every other channel.

These objectives are valid whether out-of-band continuous low-level (−20 dBm0) signalling waves or out-of-band burst-mode (at a rate of 10 Hz) high-level (−5 dBm0) signalling waves are used.

24 Protection and suppression of in-band signalling

24.1 *Protection of in-band signalling*

This point is under study.

24.2 *Disturbances of telephone channels by in-band signalling*

This point is under study.

25 Mutual interference between pilots and out-of-band signalling

The transmultiplexers capable of emitting and receiving out-of-band signalling should meet the provisions of the Recommendation cited in [17].

26 Short- and long-term stability

Measuring method C.

When a sine-wave signal level 0 dBm0 is applied at the analogue input of the transmultiplexer, the level measured at the analogue output should not vary by more than ± 0.2 dB during 10 consecutive minutes of normal operation, more than ± 0.5 dB during 30 consecutive days nor by more than ± 1 dB for one year, allowing for the authorized variations of power supply voltages and temperature.

References

[1] CCITT Recommendation *Recommendations relating to the accuracy of carrier frequencies*, Vol. III, Fascicle III.2, Rec. G.225, § 1.

[2] CCITT Recommendation *Pilots on groups, supergroups, etc.*, Vol. III, Fascicle III.2, Rec. G.241, § 1.

[3] *Ibid.*, § 2.

[4] *Ibid.*, § 3.

[5] CCITT Recommendation *Assumptions for the calculation of noise on hypothetical reference circuits for telephony*, Vol. III, Fascicle III.2, Rec. G.223, Table 3/G.223, § 6.

[6] CCITT Recommendation *Measurement of circuit noise in cable systems using a uniform-spectrum random noise loading*, Vol. III, Fascicle III.2, Rec. G.228, § A.1, A.2.2.

[7] CCITT Recommendation *Assumptions for the calculation of noise on hypothetical reference circuits for telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 2.1.

[8] CCITT Recommendation *Measuring method and through-connection filters for noise produced by modulating equipment*, Vol. III, Fascicle III.2, Rec. G.230.

[9] CCIR Recommendation *Measurement of performance by means of a signal of a uniform spectrum for systems using frequency-division multiplex telephony in the fixed satellite service*, Vol. IV, Rec. 482-1, ITU, Geneva, 1978.

[10] CCITT Recommendation *Assumptions for the calculation of noise on hypothetical reference circuits for telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 7.

[11] CCITT Recommendation *Conventional telephone signal*, Vol. III, Fascicle III.2, Rec. G.227.

[12] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, §§ 5.1, 5.2.

[13] CCITT Recommendation *Through-connection of groups, supergroups, etc.*, Vol. III, Fascicle III.2, Rec. G.242, § 1.

[14] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, §§ 12.1, 12.2 and Annex A.

[15] CCITT Recommendation *Signal sender*, Vol. VI, Fascicle VI.4, Rec. Q.414, Figure 6/Q.414.

[16] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232.

[17] *Ibid.*, § 12.3 and Annex B.

CHARACERISTICS OF 60-CHANNEL TRANSMULTIPLEXING EQUIPMENTS

(Geneva, 1980)

1 Introduction

The 60-channel transmultiplexer is a transmultiplexing equipment which satisfies Recommendations G.791 and G.792 and provides interconnection between two digital signals at 2048 kbit/s and an analogue supergroup (60-channel TMUX-S) or five analogue groups (60-channel TMUX-P). The present Recommendation is, for the time being, specific to TMUX-S. TMUX-P will be taken into account in subsequent studies.

2 Digital interfaces

2.1 *Coding law*

The coding law used is A-law specified in Recommendation G.711.

2.2 *Interfaces*

The 2048-kbit/s interfaces satisfy Recommendation G.703, § 5.

2.3 *Frame structure*

The 2048-kbit/s frame structure satisfies Recommendation G.732, § 2.

2.4 *Multiframe structure*

The multiframe structure of time slot 16 satisfies Recommendation G.732, §§ 4.2.1, 4.2.2 and 4.2.3.

3 Analogue interfaces

3.1 *Ports*

The analogue interface consists of a 60-channel supergroup (band 312-552 kHz) which satisfies Recommendation G.233 [1].

The preferred signal levels at the supergroup distribution frame should be:

- for sending −36 dBr
- for receiving −30 dBr

The impedances are: 75 ohms (unbalanced).

3.2 *Pilots*

The 60-channel transmultiplexer should transmit the following pilots:

TMUX-S: A supergroup pilot with a frequency 411 920 Hz and a level of −20 dBm0,

one pilot per group with a level of −20 dBm0 and frequencies of:

Group 1: 335 920 Hz

Group 2: 383 920 Hz

Group 3: 431 920 Hz

Group 4: 479 920 Hz

Group 5: 527 920 Hz

The characteristics relating to the generation and transmission of these pilots are given in Recommendation G.241 [2].

3.3 *Pilot detection and regulation*

The transmultiplexer may or may not regulate levels on the basis of the levels of the group and supergroup pilots. Detection of the levels of the group pilots mentioned in § 3.2 should, however, be effected to ensure operation of the interruption control system (Recommendation Q.416 [3]), when R2 signalling is used.

4 Correspondence between analogue and digital channels

A fixed correspondence is established between the analogue and digital channels. The correspondence shown in Table 1/G.793 (which facilitates the transfer of alarms and results in a natural order of the channels on the analogue side) is recommended.

TABLE 1/G.793

PCM 1 channels 1 to 12	Group 1 312-360 kHz
PCM 1 channels 13 to 24	Group 2 360-408 kHz
PCM 1 channels 25 to 30	Group 3 408-432 kHz
PCM 2 channels 1 to 6	Group 3 432-456 kHz
PCM 2 channels 7 to 18	Group 4 456-504 kHz
PCM 2 channels 19 to 30	Group 5 504-552 kHz

5 Plesiochronism of incoming PCM streams

Sixty-channel transmultiplexers should be able to accept two mutually plesiochronous incoming PCM streams within the limits laid down in Recommendation G.703 (bit rate 2048 kbit/s, $\pm 50 \cdot 10^{-6}$).

In the case of transmultiplexers with digital filtering, this means that the two input ports at 2048 kbit/s are fitted with frame aligners (jump or repetition of samples) and multiframe aligners for synchronizing the incoming PCM streams with the transmultiplexer clock. In order to avoid a major slip frequency, the two incoming PCM streams should be either synchronous with the transmultiplexer or plesiochronous with each other and with the transmultiplexer clock, so that Recommendation G.811 on the plesiochronous network is satisfied.

6 Synchronization of transmultiplexer

The transmultiplexer must produce virtual analogue carrier frequencies with the accuracy specified in Recommendation G.225 [4] ($\pm 10^{-7}$).

For this purpose, it is recommended:

a) either that the transmultiplexer should have an internal clock of sufficient accuracy;

b) or that the transmultiplexer should be synchronizable with an external signal which may be:

   1) a frequency (see Note 3) produced by a central generator;

   2) or one of the incoming PCM streams which has sufficient accuracy (this may be the case, for example, when this PCM stream at 2048 kbit/s is produced by a TDM switching equipment). If both 2048-kbit/s streams are of sufficient accuracy, the use of PCM stream No. 1 is preferred. In most cases this avoids, at the digital filtering transmultiplexer input, the slipping phenomena which, when too frequent, cause high error rates on in-band data signals.

Note 1 – In the case of a digital filtering transmultiplexer, when synchronization on one of the incoming PCM streams is not possible, the remote digital terminal should have the sending side synchronized with the receiving side so as to avoid slipping at the transmultiplexer input.

Note 2 – In the case of external synchronization and if the transmultiplexer has an internal clock, the TMUX clock should have a minimum accuracy ($\pm 50 \cdot 10^{-6}$ for example) and a local alarm should be given in the event of a fault in the synchronization system or in the absence of the synchronization signal.

Note 3 – The possibility of recommending one specific frequency for the external synchronization signal is being studied.

7 Signalling

Different kinds of signalling systems can be envisaged.

7.1 *In-band signalling*

The 60-channel transmultiplexer is transparent for channel-associated in-band signalling. The fault conditions and consequent actions must be studied further for this type of signalling.

7.2 *Common channel signalling*

In the case when common channel signalling must be routed through the transmultiplexer, attention is drawn to the fact that the transmission capabilities of a channel in the transmultiplexer is limited to the band 300-3400 Hz (i.e. data rates corresponding to this frequency band).

In the opposite case, when common channel signalling is not routed through the TMUX, no special problems are recognized.

In both cases, the fault condition and consequent actions must be studied further.

7.3 *Out-of-band signalling*

As regards the Signalling System R2, two methods of conversion are envisaged: one, the "1 bit method", is reserved for use in national networks and is described in Annex A to this Recommendation; the other, the "2 bit method", is to be used in the case of international interconnections and should conform to the following specifications.

The transmultiplexer, or an additional equipment associated with it, converts the analogue version to the 2-bit digital version of the R2 line Signalling System, and vice versa. In all cases, the transmultiplexer should provide the following facilities for signalling:

a) *Analogue side*

   1) recognition of the signalling frequency at 3825 Hz in accordance with Recommendation Q.415 [5];

   2) transmission of the signalling frequency at 3825 Hz in accordance with Recommendation Q.414 [6];

   3) supervision of group pilots (and supergroup pilots if necessary) in accordance with Recommendation Q.416 [3].

b) *Digital side*

1) extraction of signalling bits *a* and *b* of time slots 16 received in accordance with the Recommendation cited in [7];

2) insertion of appropriate signalling data in bits *a* and *b* of time slots 16 transmitted in accordance with the Recommendation cited in [7];

3) detection of PCM system faults.

The conversion between the analogue and digital versions of the R2 line Signalling System should be made in accordance with [8]. When the conversion is made in an external equipment, the transmultiplexer should supply the necessary ports.

8 Fault conditions and consequent action

§ 8 concerns only transmultiplexers operated in conjunction with Signalling System R2, 2-bit digital version.

8.1 *Principles of the action to be taken*

The principles governing the handling of alarms is as follows: The behaviour of a transmultiplexer vis-a-vis a 30-channel PCM multiplex should be the same as that of another 30-channel PCM multiplex. However, the transmultiplexer performs certain functions peculiar to digital multiplexing equipments such as the transmission of the Alarm Indication Signal (AIS). Vis-a-vis a group modulator, it should behave like another group modulator.

Table 2/G.793 summarizes the fault conditions and the consequent actions.

TABLE 2/G.793

Fault conditions and consequent actions, applicable if Signalling System R2, 2-bit digital version, is used

	Fault conditions	Consequent actions						
		Prompt maintenance alarm	Alarm sent back		Blocking of faulty speech channels	Information to be taken into account in conversion	Transmission of alarms	
			Bit 3 0 to 1 (see Note 1)	Bit 6 time slot 16, frame 0 to 1 (see Note 1)			Pilot cut-out	AIS sent (see Note 1)
PCM alarms	Loss of signal Error ratio $>10^{-3}$ Loss of frame alignment (see Note 1)	Yes (see Note 2)	Yes		Yes PCM → FDM	a = b = 1	(see Note 3)	
PCM alarms	Loss of multiframe alignment (see Note 1)	Yes (see Note 2)		Yes		a = b = 1	(see Note 3)	
PCM alarms	Reception of bit 3, time slot 0 or bit 6, time slot 16, frame 0 (see Note 1)					a = b = 1		
FDM alarms	Absence of group pilot (see Note 4)	Yes			Yes FDM → PCM	Absence of pilot		Yes (see Note 5)
FDM alarms	Absence of supergroup pilot (see Note 6)	Yes				Absence of pilot		
FDM alarms	Delta pilot (see Note 7)	Yes						
	Failure of power supply	Yes					Yes, if possible	Yes, if possible
	System failure (see Note 8)	Yes					Yes	Yes (see Note 5)
	Synchronization failure (see Note 9)	Yes						

Note 1 – The fault conditions "Loss of signal at 2 Mbit/s", "Error ratio $>10^{-3}$", "Loss of frame alignment", "Loss of multiframe alignment", "Reception of bit 3, time slot 0", "Reception of bit 6, time slot 16, frame 0" and the consequent action "Bit 3, time slot 0 to 1", "Bit 6, time slot 16, frame 0 to 1" and "AIS sent" are defined in Recommendation G.732.

Note 2 – The 60-channel transmultiplexer should be able to detect the alarm indication signal (AIS) on incoming streams at 2048 kbit/s. When AIS is detected, the prompt maintenance indication associated with the loss of frame alignment, with an excessive error rate or with the loss of multiframe alignment should be blocked.

Note 3 – This action is not necessary when the digital version of Signalling System R2 is used, but may be useful with other applications.

Note 4 – The definition of absence of group pilot used for the operation of the interruption control system is given in the Recommendation cited in [9].

Note 5 – The AIS is sent only if the 30 channels of a single PCM stream are in the alarm condition.

Note 6 – Detection of "absence of supergroup pilot" is not obligatory.

Note 7 – The concept of "delta pilot" corresponds to a variation on the level of the pilot from its nominal value by more than ± 4 dB, as stated in [10]. This applies only to transmultiplexers with automatic internal level regulation.

Note 8 – The "system" fault condition corresponds to a fault on the transmultiplexer detected by the transmultiplexer's supervision system, when it has one.

Note 9 – The "synchronization" fault is that mentioned in § 6. The necessity and the method of detecting this fault are being studied.

ANNEX A

(to Recommendation G.793)

Possible arrangements for national use for the handling of signalling in the transmultiplexer

A.1 In national networks, the following arrangements, conforming to [11] may be used when the circuits connected to the transmultiplexer are operated with the R2 Signalling System.

The 60-channel transmultiplexer establishes a correspondence between the signalling data carried by time slots 16 of the PCM frames and the out-of-band signalling frequencies at 3825 Hz. The specifications concerning these signalling frequencies are contained in Recommendations Q.414 [6] and Q.415 [5].

The signalling bit *a* associated with a channel is used to transmit the presence or absence of the signalling frequency in that channel. The signalling bit *b* associated with a channel is used to transmit alarm information to the channel in the FDM→ PCM direction, when the loss of the group pilot carrying the channel is detected.

In this organization, the principles governing the handling of alarms is as follows:

- priority is given to the correct functioning of the interruption control system (Recommendation Q.416 [3]);
- the behaviour of a transmultiplexer vis-a-vis a 30-channel PCM multiplex should be the same as that of another 30-channel PCM multiplex. However, the transmultiplexer performs certain functions peculiar to digital multiplexing equipments, such as the emission of the AIS. Vis-a-vis a group modulator, it should behave like another group modulator.

Table A-1/G.793 summarizes fault conditions and consequent action.

A.2 The same solution may also be used for other national out-of-band signalling systems.

A.3 In some cases, it may be desirable for the transmultiplexer to provide locally the information control information relating to the various groups.

TABLE A-1/G.793

Fault conditions and consequent actions, applicable for national networks where Signalling System R2, 1-bit analogue version, is used

	Fault conditions	Consequent actions							
		Prompt maintenance alarm	Alarm sent back		Blocking of faulty speech channels	Blocking of faulty signalling channels	Transmission of alarms		
			Bit 3, time slot 0 to 1 (see Note 1)	Bit 3, time slot 16, frame 0 to 1 (see Note 1)			Pilot cut-out	AIS sent (see Note 1)	Bit *b*, time slot 16 to 1 (see Note 2)
PCM alarms	Loss of signal Error ratio $>10^{-3}$ Loss of frame alignment (see Note 1)	Yes (see Note 3)	Yes		Yes PCM → FDM	Yes PCM → FDM	Yes (see Note 4)		
PCM alarms	Loss of multiframe alignment (see Note 1)	Yes (see Note 3)		Yes		Yes PCM → FDM	Yes (see Note 4)		
FDM alarms	Absence of group pilot (see Note 5)	Yes			Yes FDM → PCM	Yes FDM → PCM		Yes (see Note 6)	Yes (see Note 6)
FDM alarms	Absence of supergroup pilot (see Note 7)	Yes							
FDM alarms	Delta pilot (see Note 8)	Yes							
	Failure of power supply	Yes					Yes, if possible	Yes, if possible	
	System failure (see Note 9)	Yes					Yes, 5 groups	Yes (see Note 6)	Yes (see Note 6)
	Synchronization failure (see Note 10)	Yes							

Note 1 – The fault conditions "Loss of signal at 2 Mbit/s", "Error ratio $>10^{-3}$", "Loss of frame alignment", "Loss of multiframe alignment" and the consequent action "Bit 3, time slot 0 to 1", "Bit 6, time slot 16 frame 0 to 1" and "AIS sent" are defined in Recommendation G.732.

Note 2 – Bit *b* of time slot 16 used for transmitting an alarm to the channel in the FDM → PCM direction so as to ensure the correct functioning of the interruption control, without having to suppress channels that are not necessarily faulty, for example, in the case of a fault on a single group.

Note 3 – The 60-channel transmultiplexer should be able to detect the alarm indication signal (AIS) on incoming streams at 2048 kbit/s. When AIS is detected, the prompt maintenance indication associated with the loss of frame alignment, with an excessive error rate or with the loss of multiframe alignment should be blocked.

Note 4 – In the PCM → FDM direction, the pilots must be cut for the 3 groups associated with a PCM multiplex signal in the event of the detection of a fault on the PCM multiplex signal stream. When a single PCM multiplex signal is faulty, this involves the blocking of 6 channels which are not faulty.

Note 5 – The definition of absence of group pilot used for the operation of the interruption control system is given in the Recommendation cited in [9].

Note 6 – The AIS is sent only if the 30 channels of a single PCM stream are in the alarm condition. The sending of AIS then has priority over the setting of bit *b* of time slot 16 to 1.

Note 7 – Detection of "absence of supergroup pilot" is not obligatory.

Note 8 – The concept of "delta pilot" corresponds to a variation on the level of the pilot from its nominal value by more than ± 4 dB, as stated in the Recommendation cited in [10]. This applies only to transmultiplexers with automatic internal level regulation.

Note 9 – The "system" fault condition corresponds to a fault on the transmultiplexer detected by the transmultiplexer's supervision system, when it has one.

Note 10 – The "synchronization" fault is that mentioned in § 6 of the text. The necessity and the method of detecting this fault are being studied.

References

[1] CCITT Recommendation *Recommendations concerning translating equipments*, Vol. III, Fascicle III.2, Rec. G.233.

[2] CCITT Recommendation *Pilots on groups, supergroups, etc.*, Vol. III, Fascicle III.2, Rec. G.241.

[3] CCITT Recommendation *Interruption control*, Vol. VI, Fascicle VI.4, Rec. Q.416.

[4] CCITT Recommendation *Recommendations relating to the accuracy of carrier frequencies*, Vol. III, Fascicle III.2, Rec. G.225.

[5] CCITT Recommendation *Signal receiver*, Vol. VI, Fascicle VI.4, Rec. Q.415.

[6] CCITT Recommendation *Signal sender*, Vol. VI, Fascicle VI.4, Rec. Q.414.

[7] CCITT Recommendation *Digital line signalling code*, Vol. VI, Fascicle VI.4, Rec. Q.421, § 3.1.2.

[8] *Use of Signalling System R2 on satellite links*, Vol. VI, Fascicle VI.4, Annex C to Signalling System R2 specifications, § 2.

[9] CCITT Recommendation *Interruption control*, Vol. VI, Fascicle VI.4, Rec. Q.416, §§ 2.4.3.2 and 2.4.3.3.

[10] CCITT Recommendation *Pilots on groups, supergroups, etc.*, Vol. III, Fascicle III.2, Rec. G.241, § 1.

[11] *Use of Signalling System R2 on satellite links*, Vol. VI, Fascicle VI.4, Annex C to Signalling System R2 specifications, § 1.

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SECTION 8

DIGITAL NETWORKS

8.1 Organization of digital networks

Recommendation G.811

PERFORMANCE OF CLOCKS SUITABLE FOR PLESIOCHRONOUS OPERATION OF INTERNATIONAL DIGITAL LINKS

(Geneva, 1976; amended at Geneva, 1980)

1 General

International digital links will be required to interconnect a variety of national networks. The national networks may be of the following forms:

a) a wholly synchronous network controlled by a single reference clock;

b) a set of synchronous subnetworks each controlled by a reference clock but with plesiochronous operation between the subnetworks;

c) a wholly synchronous network with two or more reference clocks which are mutually synchronized by national links;

d) a wholly plesiochronous national network.

All international links will be terminated on aligning equipments within which slips will occur.

The international plesiochronous network should be organized so that the theoretical rate of occurrence of slips (i.e. the design rate of slips, based on ideal undisturbed conditions) in any 64-kbit/s channel is not greater than one in every 70 days per digital international link. Aligning equipment may take the form of frame aligners located at the periphery of the exchange which introduce slips of one frame, or the equipment may be integrated into the switch structure and introduce slips of one octet. The maximum slip rate per international digital connection is given in Recommendation G.822.

Where a national network or subnetwork is controlled by a single reference clock the frequency of the clock must be unaffected by control signals generated within the national network or subnetwork.

Where more than one reference clock exists in a national network and where these reference clocks are mutually synchronized then, apart from controls from the mutual synchronization links, the frequencies of the clocks must be unaffected by control signals generated within the national network. Further, any disturbance introduced by the mutual synchronization link must not cause the inaccuracy of the reference clock to exceed those in the specification of § 4 below.

Where a national network is wholly plesiochronous, each national clock controlling a network node participating in an international connection should satisfy the specification of § 4 below.

All clocks controlling network nodes with international links must have a long term frequency inaccuracy of not greater than 1 in 10^{11}. Such clocks will need a very high reliability and are likely to include replication of equipment in order to ensure continuity of output. However, any phase discontinuity, due to internal operations within the clock or any other cause, should only result in a lengthening or shortening of the timing signal pulse and must not cause a phase discontinuity in excess of 1/8 of a unit interval on the outgoing digital stream from the network node.

Note – A network node may include a digital exchange, a synchronous digital multiplex or other synchronous equipment.

2 Reliabilty of clocks

2.1 *Unavailability and degradation of reference clocks*

Faults which degrade or disable the reference frequency supply to a network cause increased slip rates across the network boundary and may introduce slips in the network itself.

The following allowances apply to that clock or collection of clocks, co-located or otherwise, which controls the frequency of a national network or subnetwork.

Table 1/G.811 indicates permitted values of the proportion of total time during which the reference clock may be unavailable or its accuracy degraded.

TABLE 1/G.811

Unavailability and degradation of reference clocks

Performance level	Reference clock inaccuracy	Maximum permissible proportion of time during which degradation occurs, referred to total time
Degraded	10^{-11} to 10^{-9} 10^{-9} to X	10^{-5} 10^{-6}
Unavailable	>X	Under study

2.2 *Unavailability and degradation of nonreference clocks*

Table 2/G.811 indicates provisional values for clocks at nodes which terminate international plesiochronous digital links.

TABLE 2/G.811

Unavailability and degradation of nonreference clocks

Performance level	Maximum inaccuracy of trunk node clock	Maximum inaccuracy of local node clock	Maximum permissible proportion of time during which degradation occurs, referred to total time
Degraded	$\pm 2 \cdot 10^{-9}$ ± Y	$\pm 10^{-8}$ ± Z	$5.7 \cdot 10^{-5}$ $5.7 \cdot 10^{-6}$
Unavailable	>Y	>Z	Under study

Note – All values in Tables 1/G.811 and 2/G.811 are provisional and require further study.

3 Interaction between plesiochronous and synchronous operation

Plesiochronous international operation will be introduced prior to international synchronization. It is important that the recommendations for plesiochronous operation should not preclude the possibility of the later introduction of synchronization. Synchronization systems will need to make adjustments to clock frequencies so that the long-term frequency of every clock is the same. Thus short-term departures greater than 1 in 10^{11} must be permitted for clocks during plesiochronous operation. These short-term departures must be limited so as not to present difficulties in the design of a synchronization system.

A period will occur when plesiochronous and synchronous links coexist within the international network and exchanges will be required to provide terminations for both types of link. It is therefore important that the synchronization controls do not cause short-term departures in the clock accuracies which are unacceptable for plesiochronous operation. The magnitudes of the short-term departures are restricted by the specifications recommended in §§ 4 and 5 below.

4 Specification for the output from a network node with a reference clock

The following applies to the output digital signal from an international node directly controlled by a reference clock.

4.1 *Definition of terms*

The definition of the **Time Interval Error (TIE)** is based on the variation, ΔT, of the time delay of a given timing signal with respect to an ideal timing signal. The TIE over a period of S seconds is defined to be the difference between the time delay values measured at the end and at the beginning of this period, see Figure 1/G.811: TIE (t) $\doteq \Delta T(t + S) - \Delta T(t)$.

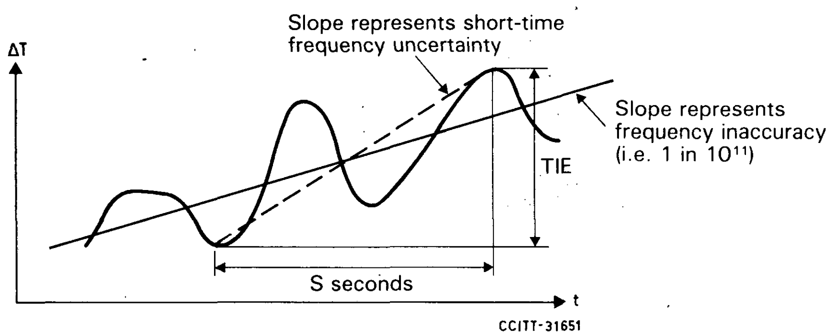


FIGURE 1/G.811
Definition of time interval error (TIE)

The corresponding **frequency uncertainty**, $\Delta f/f$, is the TIE divided by the duration of the period (i.e. S seconds).

4.2 *Specification of time interval error (TIE)*

The TIE over a period of S seconds shall not exceed the following limits:

a) (100 S) ns + 1/8 unit interval (UI); this is applicable to values of S less than 5.

   These limits may be exceeded in cases of infrequent internal testing or re-arrangement operations within the exchange. In such cases, the following conditions should be met:

   The TIE over any period up to 2^{11} UI should not exceed 1/8 of a UI. For periods greater than 2^{11} UI the phase variation for each interval of 2^{11} UI should not exceed 1/8 UI up to a total maximum TIE of 500 ns;

b) (5 S + 500) ns, applicable to values of S between 5 and 400;

c) (10^{-2} S + 2500) ns, applicable to values of S greater than 400.

Note 1 – The resulting overall specification is illustrated in Figure 2/G.811.

Note 2 – The allowance 2500 ns is intended to cater for ageing and other effects. It is not intended that relatively short-term wander of this magnitude should occur.

Note 3 – The basic value of 1/8 UI indicated in a) above is limited by the requirements of line regenerators. Phase discontinuities of this magnitude can occur due to internal operations within the clock (see § 2), e.g., protection switching or discrete phase adjustments within a synchronization scheme.

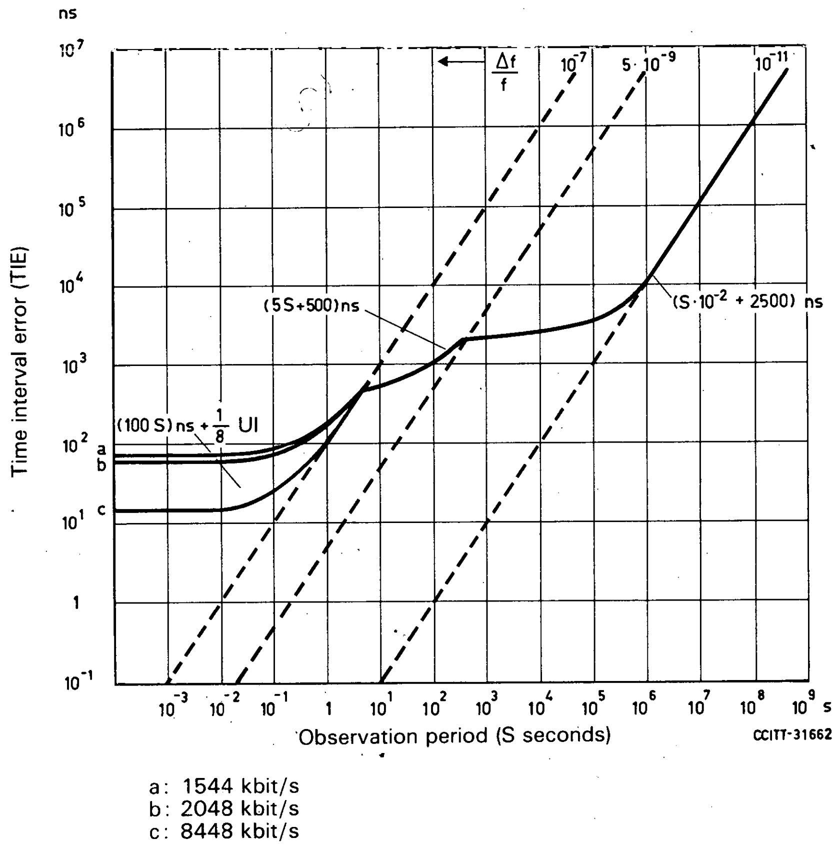


FIGURE 2/G.811

Permissible time interval error (TIE) as a function of observation period

5 Specification for the output from a network node with a nonreference clock

The following applies to the output digital signal from any international node, regardless of the national synchronization system.

The TIE for the ranges of periods designated a) and b) in § 4.2 should not exceed the limits given there; for the range c), the constant term (to replace 2500 ns) is under study.

The boundary between ranges b) and c) will be defined when the constant term will have been determined (see Note).

Note – The constant term of the expression for range c) will be (2500 + N) ns. The value of N will be determined taking into account the clauses of Recommendation Q.503 [1].

6 Use of satellite systems in an international plesiochronous digital network

6.1 *Where switching mode satellites are not employed*

Where independently synchronized national networks are interconnected via a digital satellite link using time division multiple access (TDMA) the timing for the satellite link will, in general, be independent of the national networks. Where circuit switching does not take place on board the satellite, it is recommended that the link be operated in a plesiochronous mode using a high accuracy (1 in 10^{11}) source for the satellite TDMA timing. Either or both earth stations may use clocks derived from the national reference clock providing that they meet the performance requirements listed in § 4.

6.2 *Where switching mode satellites are employed*

Under study.

7 Forms of aligning equipment

The following two forms of aligning equipment are suitable for the termination of international digital sections:

- a frame aligner realized as a peripheral unit;
- a slot aligner which forms an integral part of the switch.

Where a frame aligner is used, a slip will consist of the insertion or removal of a consecutive set of digits amounting to a frame. In the case of frame structures as in Recommendations G.732, G.733 and G.734 the slip can consist of one complete frame. It is of importance that the maximum and mean delays introduced by the frame aligner should be as small as possible in order to minimize the delay through the exchange. The limits for these delays are under study taking into account the requirement for the delay through the exchange. It is also of importance that, after the frame aligner has produced a slip, it should be capable of absorbing changes in the arrival time of the frame alignment signals approaching the duration of a frame before a further slip is necessary. The requirement of 1 slip in 70 days per exchange in any 64-kbit/s channel must not be exceeded.

Where a slot aligner is used, a slip will consist of the insertion or removal of the eight digits of a channel time slot in one or more 64-kbit/s channels. Because slips may occur on different channels at different times, special control arrangements will be necessary within the switch if the sequence integrity of the multiple time-slot services is to be maintained. The control arrangements will need to be able to deal with the jitter on the inputs arising from clock phase variations (see §§ 4 and 5 above) such that the requirement of 1 slip in 70 days per exchange is not exceeded.

Reference

[1] CCITT Recommendation *Technical parameters*, Vol. VI, Fascicle VI.5, Rec. Q.503.

8.2 Quality and availability targets

Recommendation G.821

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

(Geneva, 1980)

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 throughput;

(c) that voice services are likely to continue to predominate and it is considered desirable that there should be a single method for describing the error performance of the ISDN, it seems necessary at this juncture to define the objective in two parts reflecting the requirements of the two major services, voice and data. In practice it is expected that both parts of the objective should be met simultaneously;

(d) that an explanation of network performance objectives and their relationship with design objectives is given in Recommendation G.102 [1].

recommends

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

1 Scope and definitions

1.1 The performance objectives are stated for a 64-kbit/s connection used for voice traffic or as a *bearer channel* for data type services.

1.2 The 64-kbit/s connection referred to is an all digital Hypothetical Reference Connection (HRX), [as identified in b) of Figure 1/G.104 [2]] of 25 000 km in length from CT3 to CT3, and in addition to that connection a digital connection from the CT3 to the primary centre, from the primary centre to the local exchange and from the local exchange to the subscriber.

1.3 The performance objective is stated in terms of an error performance parameter which is defined as follows:

The percentage of averaging periods 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.

1.4 For voice services the parameter is based on an averaging period $T_0 = 1$ minute and a threshold BER of $1 \cdot 10^{-6}$.

1.5 For data services the parameter is based on an averaging period $T_0 = 1$ second and a threshold BER of zero. This is equivalent to the concept of error free seconds (EFS).

2 Performance objective

The performance objectives for international ISDN connections as identified in §§ 1.1 and 1.2 are shown in Table 1/G.821.

It should be noted that total time (T_L) is split into two parts, namely the time for which the connection is deemed to be available and the time when it is unavailable. As a result of further studies, the precise meaning and an overall objective will be established for the availability of a connection. Table 1/G.821 refers to the period when the connection is available. A connection is considered to be unavailable and not included in Table 1/G.821 when the BER is worse than $1 \cdot 10^{-3}$ for periods exceeding *n* seconds. Values for *n* in the range 1 to 10 seconds have been proposed and will be the subject of further study.

It is expected that this criterion will be only one of the several factors contributing to the total unavailability of a connection.

Of the time that the connection is available, the objective expresses the percentage time that the connection can have a degraded performance.

TABLE 1/G.821

Error performance objectives for international ISDN connections

$T_0 = 1$ minute		$T_0 = 1$ second	
BER in 1 minute	Percentage of available minutes	BER in 1 second	Percentage of available seconds
Worse than $1 \cdot 10^{-6}$	Less than 10%	>0	Less than 8%
Better than $1 \cdot 10^{-6}$	More than 90%	0	More than 92% (% EFS)

Note 1 – It is intended that international ISDN connections should meet the requirements in the table for both values of T_0.

Note 2 – The limits proposed are based on the best knowledge currently available but are subject to review in the future in the light of further studies. For the time being the limits should be considered as being provisional.

A BER threshold of $1 \cdot 10^{-5}$ has been proposed as an alternative to $1 \cdot 10^{-6}$ and it is possible that the ultimate value may lie in the range $1 \cdot 10^{-5}$ to $1 \cdot 10^{-6}$. In considering this threshold, the percentage of available minutes should be kept under review.

Note 3 – Total time T_L has not been determined since the period may depend upon the application. A period of the order of any one month is suggested as a reference.

Note 4 – The unavailability threshold of $1 \cdot 10^{-3}$ may need review, particularly in its effect on some services such as facsimile, where a value of $1 \cdot 10^{-4}$ may prove to be advisable.

3 Allocation of overall objectives

For the time being no specific allocation is proposed, but Table 2/G.821 suggests apportionments for study.

For the time being it is postulated that the permissible end-to-end impairment will be allocated on the basis of approximately 50-60% to the local exchange to local exchange part of the connection and 20-25% to each of the local exchange to subscribers parts. However, it should be noted that this allocation is only intended as a guideline and for some national networks other allocations might be appropriate. The latter is likely to be acceptable so long as that part ultimately allocated to the national portion is not exceeded.

TABLE 2/G.821

Allocation of error performance objectives

Portion (See Recommendation G.104 [3])	% of total impairment
International portion together with the sum of both national portions	50 - 60%
The sum of both local portions	40 - 50%

ANNEX A

(to Recommendation G.821)

Some comments on the Recommendation and its relevance to services utilizing higher bit rates

A.1 In a practical network, the distribution of errors for connections meeting that part of the objective defined for averaging periods of 1 minute (see § 1.4) should be such that the 92% EFS part of the objective can be achieved.

A.2 Studies to determine the typical distribution of errors are taking place and ultimately, by means of a model, it might be possible to define a mathematical relationship between the two methods of defining the error performance objective as described in §§ 1.4 and 1.5.

A.3 This Recommendation deals with performance objectives for a 64-kbit/s HRX and therefore does not apply to broadcast quality TV or other higher bit rate services. It is generally expected that existing and planned designs of higher bit rate systems, with the possible exception of satellite systems, will be adequate for TV. Nevertheless, it seems appropriate to define an HRX for TV, and this done, to establish error performance objectives using the error performance parameter defined in § 1.3. The severe subjective effects of loss of TV synchronization suggest that a much shorter averaging interval (T_0), and a much lower percentage allowance of intervals above threshold than those cited above may be appropriate. The final choice of values is likely to depend on the TV coding technique ultimately recommended.

References

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

[2] CCITT Recommendation *Hypothetical reference connections (digital network),* Vol. III, Fascicle III.1, Rec. G.104, Figure 1/G.104, b).

[3] CCITT Recommendation *Hypothetical reference connections (digital network),* Vol. III, Fascicle III.1, Rec. G.104.

CONTROLLED SLIP RATE OBJECTIVES ON AN INTERNATIONAL DIGITAL CONNECTION

(Geneva, 1980)

1 General

This Recommendation deals with end-to-end *controlled octet slip rate* objectives for 64-kbit/s international digital connections. The objectives are presented for various operational conditions in relation to the subjective evaluation of connection quality.

Under design conditions for digital network nodes and within defined normal transmission characteristics, it may be assumed that there are zero slips in a synchronized digital network. However, the defined transmission characteristics can be exceeded under operating conditions and cause a limited number of slips to occur even in a synchronized network.

Under temporary loss of timing control within a particular synchronized network, additional slips may be incurred, resulting in a larger number of slips for an end-to-end connection.

With plesiochronous operation, the number of slips on the international links will be governed by the sizes of buffer stores and the accuracies and stabilities of the interconnecting national clocks.

2 Scope and considerations

2.1 The end-to-end slip rate performance should satisfy the service requirements for telephone and nontelephone services on a 64-kbit/s digital connection in an ISDN.

2.2 The slip rate objectives for an international end-to-end connection are stated with reference to the Hypothetical Reference Connection (HRX) identified in b) of Figure 1/G.104 [1], of 25 000 km in length.

2.3 It is assumed that international exchanges (CTs) are interconnected by international links which are operating plesiochronously, using clocks with accuracies as specified in Recommendation G.811. It is recognized that 1 slip in 70 days per plesiochronous interexchange link is the resulting maximum theoretical slip rate, taking into account clock accuracies according to Recommendation G.811 only, and providing the transmission and switching requirements remain within their design limits.

2.4 In a practical international end-to-end connection containing both international and national portions, the slip rate may significantly exceed the value computed from n plesiochronous interexchange links due to various design, environmental and operational conditions in international and national sections. These include:

a) configuration of the international digital network,

b) national timing control arrangements,

c) wander due to extreme temperature variations,

d) operational performance characteristics of various types of switches and transmission links (including diurnal variations of satellite facilities),

e) temporary disturbances on transmission and synchronization links (network rearrangements, protection switching, human errors, etc.).

Note – The maximum number, n, of plesiochronous interexchange links is under study.

2.5 A threshold of *satisfactory slip* performance is a suitable compromise between desired service requirements and normally achievable performance. Slip levels exceeding this threshold will begin to affect performance and can be considered to cause *degraded service*. In order to ensure that a trend of performance has been identified, the threshold rate must be measured over a sufficient period to record a significant number of slips. An objective limit is placed on the total time that the threshold is exceeded during the period of one year.

2.6 While some services may still be operational under sustained loss of timing information or during a severe nodal clock fault condition, the performance of a connection may be at a level at which a significant loss of service occurs. The slip rate above this threshold will be considered to provide *unacceptable performance* between certain nodal points in the network.

3 Slip performance objective

Slip is one of several contributing factors to impairment of a digital connection. The performance objectives for the rate of octet slips on an international connection of 25 000 km in length or a corresponding bearer channel are given in Table 1/G.822. Further study is required to confirm that these values are compatible with other objectives, e.g. the error performance as listed in Recommendation G.821.

TABLE 1/G.822

Performance objectives for slip rate on a 64-kbit/s international connection or bearer channel [a]

Performance	Mean slip rate thresholds	Measurement period	Network objectives as percentage of total time [b]
Connection unacceptable	≥1 slip in 2 min	1 h	<0.1%
Connection acceptable but degraded	<1 slip in 2 min and >1 slip in 5 h	24 h	<1.0%
Connection satisfactory	≤1 slip in 5 h	24 h	≥99%

[a] All values are provisional. The slip rate thresholds have been subject to more investigations than the other numbers in the table.

[b] Total time ≥ 1 year.

4 Allocation of impairments

4.1 The probability of more than one section of the network experiencing excessive slips which will simultaneously affect any given connection, is low. Advantage is taken of this factor in the allocation process.

4.2 Because the impact of slips occurring in different parts of a connection will vary in importance depending upon the type of service and the level of traffic affected, the allocation process includes placing tighter limits on slips detected at international and national transit exchanges and less stringent limits on small local exchanges.

4.3 The recommended allocation process is based on subdividing the percentage of time objectives for degraded or unacceptable service (Table 1/G.822). A provisional allocation is made to the various portions of the HRX as shown in Table 2/G.822.

TABLE 2/G.822

Allocation of network objectives a)

Portion of HRX in b) of Figure 1/G.104 [1]	Allocated percentage of each objective in table 1/G.822	Objectives as percentage of total time b)	
		Connection degraded	Connection unacceptable
International portion	2%	0.02%	0.002%
Each national portion	9%	0.09%	0.009%
Each local portion	40%	0.4%	0.04%

a) All values are provisional.

b) Total time $\geqslant$ 1 year.

Reference

[1] CCITT Recommendation *Hypothetical reference connections (digital network)*, Vol. III, Fascicle III.1, Rec. G.104, Figure 1/G.104, b).

SECTION 9

DIGITAL LINE TRANSMISSION SYSTEMS

9.0 General

Recommendation G.901

GENERAL CONSIDERATIONS ON DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS

(Geneva, 1980)

1 Digital line section and digital line systems

Digital line sections are defined as component parts of digital paths operating at particular bit rates and may be regarded as "black boxes", the inputs and outputs of which are the recommended "equipment interfaces" as given in Recommendation G.703 for hierarchical bit rates or in the Recommendations of Subsection 9.2 for nonhierarchical bit rates. Recommendations on digital line sections relate to networks; those Recommendations concerning performance provide objectives to be realized in networks (network performance objectives).

Digital line systems are the means of providing digital line sections. Recommendations on digital line systems may recognize, for digital line sections operating at a given bit rate, specific transmission media and transmission techniques (e.g. coaxial cable, regenerative transmission). Performance requirements of digital line systems are for the guidance of system designers (equipment design objectives) and may be related to hypothetical reference digital paths of defined constitution.

All digital line systems operating at a given bit rate shall comply with the characteristics of the digital line section at the same bit rate.

2 International interconnections

For international interconnections CCITT recommends:

1) as preferred solution interconnections at equipment interfaces operating at hierarchical bit rates, the connections shown in Figures 1a)/G.901 and 2a)/G.901;

2) as second priority solution interconnections at equipment interfaces operating at nonhierarchical bit rates, the connections shown in Figure 2b)/G.901;

3) that line interfaces as indicated in Figure 1b)/G.901 and Figure 2c)/G.901 are not intended to be used as international interconnection points.

All parameters necessary for interconnection at equipment interfaces will be covered by that part of the Recommendation that deals with "Characteristics of digital line sections".

Equipment interfaces as used in the following Recommendations refer to interfaces as specified in Recommendation G.703 and may either refer to a direct connection between terminating equipments or to a connection at a digital distribution frame.

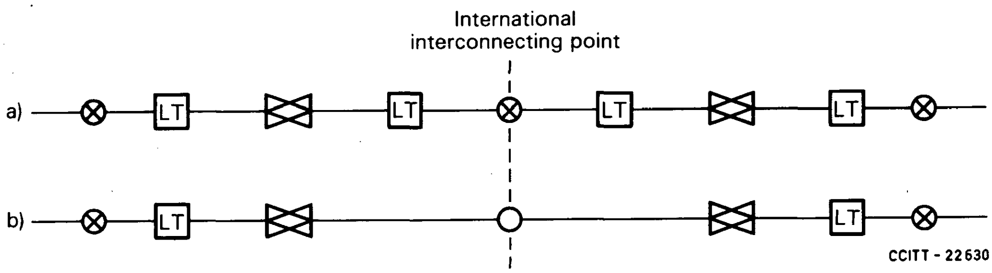


FIGURE 1/G.901

Alternatives for interconnection of line transmission systems operating at hierarchical bit rates.

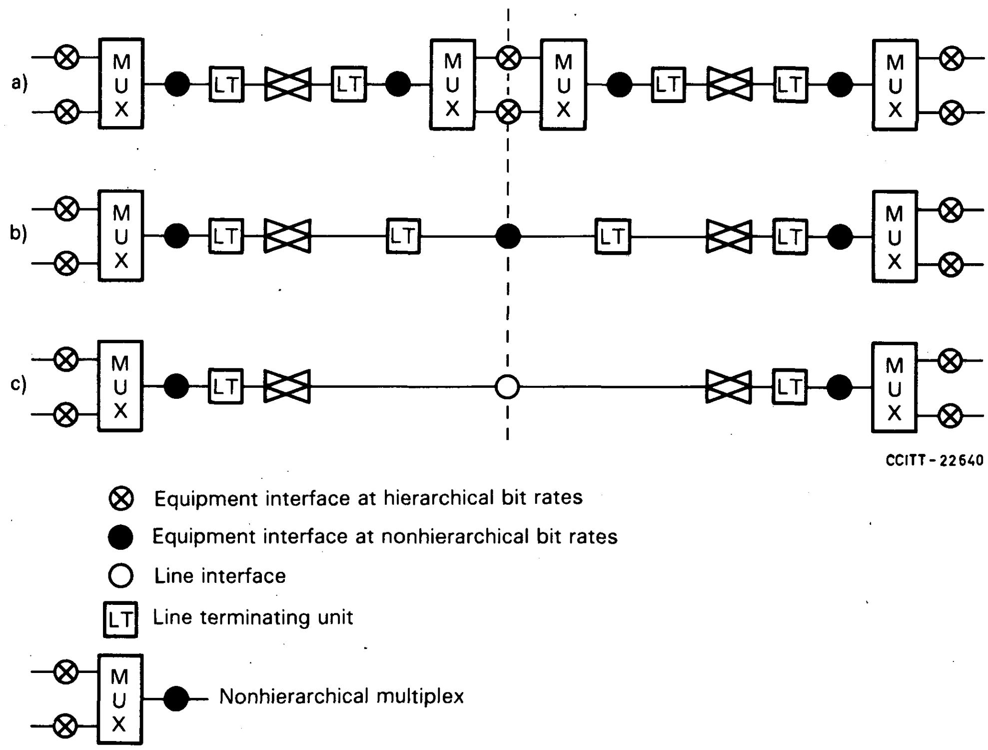


FIGURE 2/G.901

Alternatives for interconnection of line transmission systems operating at non-hierarchical bit rates

9.1 Digital line transmission systems on cable at hierarchical bit rates [1]

Recommendation G.911

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 1544 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *Characteristics of interfaces*

The digital interfaces at 1544 kbit/s should comply with Recommendation G.703.

1.2 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in absence of input jitter, jitter transfer function and availability will be made taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.2.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.2.2 *Jitter*

1.2.2.1 *Lower limit of maximum tolerable jitter at the input*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.2 *Limit of output jitter*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.3 *Maximum output jitter in absence of input jitter*

Under study.

1.2.2.4 *Jitter transfer functions*

Under study.

Note – A proposal for specifying test sequences for jitter measurements on digital line sections is given in Annex A.

1.2.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3 *Fault conditions and consequent actions*

Under study.

[1] Recommendation G.911 of Volume III-2 of the Orange Book has been deleted.

2 Characteristics of digital line systems on symmetrical pair cables

The characteristics of digital line systems are under study.

The following list of characteristics is of provisional nature.

2.1 *Type of system*

2.1.1 *Transmission medium*

2.2 *Working conditions*

2.2.1 *Environmental conditions*:

- temperatures;
- humidity;
- pressurization;
- interferences from external sources.

2.3 *Overall design features*

2.3.1 *Interference to other systems*

2.3.2 *Reliability*

2.3.3 *Availability*

2.3.4 *Repeater noise margin* (against specified error rates and line loss)

2.3.5 *Jitter performance*

Note – In establishing values for availability the possibility of having protection switching facilities should also be considered.

2.4 *Specific design features*

2.4.1 *Type of power feeding*

2.4.2 *Repeater spacing*

2.5 *Maintenance strategy*

2.5.1 *Type of supervision and fault location* (e.g. in-service or out-of-service supervision)

2.5.2 *Fault conditions and consequent actions*

Note – The fault conditions and consequent actions in this section should be complementary to those recommended for digital line sections.

3 Characteristics of digital line systems on optical fibre cables

For parameters see § 2.

ANNEX A

(to Recommendation G.911)

Test sequencies for jitter measurements on digital line sections

A.1 *Introduction*

The bandwidth of the jitter spectrum at the ouput of a chain of digital repeaters is shown [1] to be a function of the Q-factor of the clock extraction circuit and the number of repeaters in tandem. The pseudo-random test sequence used when measuring the output jitter must have adequate spectral content within the jitter bandwidth of the system being measured. Jitter measurements for various pseudo-random sequence lengths are given in [2]. The measurements show that large measurement errors and inconsistencies occur if the test pattern repetition frequency is about the same as the jitter bandwidth of the system under test. These inconsistencies are considerably reduced but still present when the pattern repetition frequency is about 1/50 of the jitter bandwidth. It is understood that the pseudo-random test sequence will be coded in accordance with the line codes at digital interfaces specified in Recommendation G.703.

A.2 *Proposal*

It is proposed that the pattern repetition frequency shall be less than 1/100 of the jitter bandwidth of the system under test.

Pattern repetition frequency $= f/L$ [Hz],

where

f is the bit rate

L is the sequence length.

Jitter bandwidth $= f_1/Q\,n$ [Hz] for large n,

where

f_1 is the frequency of the clock that is extracted from the incoming signal by the timing recovery circuit

Q is the Q-factor of one repeater

n is the number of repeaters in tandem.

$$\text{Thus } f/L \leqslant f_1/100\,Q\,n$$

$$\text{and } L \geqslant 100\,Q\,n\,f/f_1$$

Examples:

for line code B6ZS $f = f_1$ and $L \geqslant 100\,n\,Q$

for a non-redundant quarternary line code $f/f_1 = 2/1$ and $L \geqslant (100\,n\,Q)\,2$.

If the system uses a scrambler or a code translation technique (e.g. 4B3T) this may be taken into account in order to reduce the length of the test sequence.

References

[1] BYRNE (C. J.), KARIFIN (B. J.) and ROBINSON (D. B.): Systematic Jitter in a chain of digital regenerators, *Bell System Technical Journal*, Vol. 42, No. 6, pp. 2679-2714, 1963.

[2] BETTS (M. C.), NORMAN (P.), WATERS (D. B.): Factory and field trial experience of the 120 Mbit/s digital line system, *Proceedings of the IEE Conference on Telecommunication Transmission*, London, 9-11 September 1975, Institution of Electrical Engineers, Conference Publication No. 131, pp. 111-114.

Recommendation G.912

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 2048 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *General features*

1.1.1 *Bit rate*

The digital line section should be able to transmit signals at a nominal bit rate of 2048 kbit/s with a tolerance of ± 50 parts per million (ppm).

1.1.2 *Special properties*

The digital line section should be bit sequence independent.

1.2 *Characteristics of interfaces*

The digital interfaces at 2048 kbit/s should comply with Recommendation G.703.

1.3 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.3.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3.2 *Jitter*

1.3.2.1 *Lower limit of maximum tolerable jitter at the input*

The digital line section should be able to tolerate at its input port a digital signal with the electrical characteristics as specified in Recommendation G.703 but modulated by sinusoidal jitter having an amplitude/-frequency relationship as defined in Recommendation G.703. Provisionally the equivalent binary content of the signal with jitter modulation should be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.2 *Limit of output jitter*

In all network situations the limit of output jitter should comply with Recommendation G.703.

Provisionally the equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.3 *Maximum output jitter in absence of input jitter*

Under study.

Provisionally the equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.4 *Jitter transfer function*

Under study.

1.3.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.4 *Fault conditions and consequent actions*

The recommendation of the full set of fault conditions and consequent actions applies specifically to digital line sections which cross international frontiers; it is recognized that within national networks Administrations may choose to apply less than the full set.

1.4.1 *Fault conditions*

The digital line section at 2048 kbit/s should detect the following fault conditions:

1.4.1.1 Failure of internal power supply

1.4.1.2 Failure of power feeding of regenerators

1.4.1.3 Error ratio $1 \cdot 10^{-3}$

Note – The criteria for activating and deactivating these alarm indications are under study.

1.4.1.4 Error ratio $1 \cdot 10^{-5}$

1.4.1.5 Loss of incoming line signal

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.6 Loss of line word alignment when alphabetic line codes are used

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.7 Loss of incoming interface signal

1.4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.912.

TABLE 1/G.912

Fault conditions and consequent actions for digital line sections at 2048 kbit/s

Equipment	Fault conditions	Maintenance Alarms		AIS to	
		Prompt	Deferred	line side	interface side
Line terminal equipment	Failure of internal power supply	Yes		Yes, if practicable	Yes, if practicable
	Failure of power feeding of regenerators	Yes			Yes, if practicable
Receiving side only	Error ratio $1 \cdot 10^{-3}$	Yes			Yes
	Error ratio $1 \cdot 10^{-5}$		Yes		
	Loss of incoming signal	Yes			Yes
	Loss of line word alignment when alphabetic line codes are used	Yes			Yes
Transmitting side only	Loss of incoming signal	Yes		Yes	

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

1.4.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally.

1.4.2.2 Deferred maintenance alarm indication generated to signify that performance is deteriorating.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 1.4.2.1 and 1.4.2.2 above, is left to the discretion of each Administration.

1.4.2.3 AIS applied to the line side (see Notes 1 and 3)

1.4.2.4 AIS applied to the interface side

Note 1 – The equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1 s.

Note 2 – The emission of the AIS in case of "Failure of power feeding" is not required when this action can be activated by detecting the failure "loss of incoming line signal".

Note 3 – The bit rate of this AIS should be within the tolerance limits defined in § 1.1.

2 Characteristics of digital line systems on symmetrical cables

For the parameters, see Recommendation G.911, § 2.

3 Characteristics of digital line systems on optical fibre cables

For the parameters, see Recommendation G.911, § 2.

Reference

[1] CCITT Recommendation *Specification for instrumentation to measure bit-error ratio on digital systems,* Vol. IV, Fascicle IV.4, Rec. O.151.

Recommendation G.913

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 6312 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *Characteristics of interfaces*

The digital interfaces at 6312 kbit/s should comply with Recommendation G.703.

1.2 *Performance standard*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.2.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.2.2 *Jitter*

1.2.2.1 *Lower limit of maximum tolerable jitter at the input*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.2 *Limit of output jitter*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.3 *Maximum output jitter in absence of input jitter*

Under study.

1.2.2.4 *Jitter transfer function*

Under study.

1.2.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3 *Fault conditions and consequent actions*

Under study.

2 Characteristics of digital line systems on symmetrical pair cables

For the parameters, see Recommendation G.911, § 2.

3 Characteristics of digital line systems on optical fibre cables

For the parameters, see Recommendation G.911, § 2.

Recommendation G.914

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 8448 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *General features*

1.1.1 *Bit rate*

The digital line section should be able to transmit signals at a nominal bit rate of 8448 kbit/s with a tolerance of ± 30 parts per million (ppm).

1.1.2 *Special properties*

The digital line section should be bit sequence independent.

1.2 *Characteristics of interfaces*

The digital interfaces at 8448 kbit/s should comply with Recommendation G.703.

1.3 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.3.1 *Error performance*

Not yet defined. (This characteristics will be defined according to the results of CCITT studies on network performance.)

1.3.2 *Jitter*

1.3.2.1 *Lower limit of maximum tolerable jitter at the input*

The digital line section should be able to tolerate at its input port a digital signal with the electrical characteristics as specified in G.703 but modulated by sinusoidal jitter having an amplitude/frequency relationship as defined in G.703. Provisionally the equivalent binary content of the signal with jitter modulation should be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.2 *Limit of output jitter*

In all network situations the limit of output jitter should comply with Recommendation G.703.

Provisionally, the equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.3 *Maximum output jitter in the absence of input jitter*

Under study.

Provisionally, the equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of $2^{15} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.4 *Jitter transfer function*

Under study.

1.3.3 *Availability*

Not yet defined. This characteristic will be defined according to the results of CCITT studies on network performance.

1.4 *Fault conditions and consequent actions*

1.4.1 *Fault conditions*

The digital line section at 8448 kbit/s should detect the following fault conditions:

1.4.1.1 Failure of internal power supply

1.4.1.2 Failure of power feeding of regenerators

1.4.1.3 Error ratio $1 \cdot 10^{-3}$

Note – The criteria for activating and deactivating of these alarm indications are under study.

1.4.1.4 Error ratio $1 \cdot 10^{-5}$

1.4.1.5 Loss of incoming line signal

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.6 Loss of line word alignment when alphabetic line codes are used

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.7 Loss of incoming interface signal

1.4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.914.

TABLE 1/G.914

Fault conditions and consequent actions for digital line sections at 8448 kbit/s

Equipment	Fault conditions	Maintenance Alarms		AIS to	
		Prompt	Deferred	line side	interface side
Line terminal equipment	Failure of internal power supply	Yes		Yes, if practicable	Yes, if practicable
	Failure of power feeding of regenerators	Yes			Yes, if practicable
Receiving side only	Error ratio $1 \cdot 10^{-3}$	Yes			Yes
	Error ratio $1 \cdot 10^{-5}$		Yes		
	Loss of incoming signal	Yes			Yes
	Loss of line word alignment when alphabetic line codes are used	Yes			Yes
Transmitting side only	Loss of incoming signal	Yes		Yes	

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

1.4.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally.

1.4.2.2 Deferred maintenance alarm indication generated to signify that performance is deteriorating.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 1.4.2.1 and 1.4.2.2 above, is left to the discretion of each Administration.

1.4.2.3 AIS applied to the line side (see Note 1 and Note 3)

1.4.2.4 AIS applied to the interface side

Note 1 – the equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1 s.

Note 2 – The emission of the AIS in case of "Failure of power feeding" is not required when this action can be activated by detecting the failure "Loss of incoming line signal".

Note 3 – The bit rate of this AIS should be within the tolerance limits defined in § 1.1.

2 Characteristics of digital line systems on symmetrical cables

For the parameters, see G.911 § 2.

3 Characteristics of digital line systems on coaxial cables

For the parameters, see G.911 § 2.

4 Characteristics of digital line systems on optical fibre cables

For the parameters, see G.911 § 2.

Reference

[1] CCITT Recommendation *Specification for instrumentation to measure bit-error ratio on digital systems*, Vol. IV, Fascicle IV.4, Rec. O.151.

Recommendation G.915

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 32 064 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *Characteristics of interfaces*

The digital interfaces at 32 064 kbit/s should comply with Recommendation G.703.

1.2 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter, in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.2.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.2.2 *Jitter*

1.2.2.1 *Lower limit of maximum tolerable jitter at the input*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.2 *Limit of output jitter*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.3 *Maximum output jitter in absence of input jitter*

Under study.

1.2.2.4 *Jitter transfer function*

Under study.

1.2.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3 *Fault conditions and consequent actions*

Under study.

2 Characteristics of digital line systems on optical fibre cables

The characteristics of digital line systems are under study.

Recommendation G.916

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 34 368 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *General features*

1.1.1 *Bit rate*

The digital line section should be able to transmit signals at a nominal bit rate of 34 368 kbit/s with a tolerance of ± 20 parts per million (ppm).

1.1.2 *Special properties*

The digital line section should be bit sequence independent.

1.2 *Characteristics of interfaces*

The digital interfaces at 34 368 kbit/s should comply with Recommendation G.703.

1.3 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.3.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3.2 *Jitter*

1.3.2.1 *Lower limit of maximum tolerable jitter at the input*

The digital line section should be able to tolerate at its input port a digital signal with the electrical characteristics as specified in G.703 but modulated by sinusoidal jitter having an amplitude/frequency relationship as defined in G.703. The equivalent binary content of the signal with jitter modulation should be a pseudorandom bit sequence of $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.2 *Limit of output jitter*

In all network situations the limit of output jitter should comply with Recommendation G.703.

The equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of length $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.3 *Maximum output jitter in absence of input jitter*

Under study.

The equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of length $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.4 *Jitter transfer function*

Under study.

1.3.3 *Availability*

Not yet defined. This characteristic will be defined according to the results of CCITT studies on network performance.

1.4 *Fault conditions and consequent actions*

1.4.1 *Fault conditions*

The digital line section at 34 368 kbit/s should detect the following fault conditions:

1.4.1.1 Failure of internal power supply

1.4.1.2 Failure of power feeding of regenerators

1.4.1.3 Error ratio $1 \cdot 10^{-3}$

Note – The criteria for activating and deactivating these alarm indications are under study.

1.4.1.4 Error ratio $1 \cdot 10^{-6}$

1.4.1.5 Loss of incoming line signal

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.6 Loss of line word alignment when alphabetic line codes are used

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.7 Loss of incoming interface signal

1.4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.916.

TABLE 1/G.916

Fault conditions and consequent actions for digital line sections at 34 368 kbit/s

Equipment	Fault conditions	Maintenance Alarms		AIS to	
		Prompt	Deferred	line side	interface side
Line terminal equipment	Failure of internal power supply	Yes		Yes, if practicable	Yes, if practicable
	Failure of power feeding of regenerators	Yes			Yes, if practicable
Receiving side only	Error ratio $1 \cdot 10^{-3}$	Yes			Yes
	Error ratio $1 \cdot 10^{-6}$		Yes		
	Loss of incoming signal	Yes			Yes
	Loss of line word alignment when alphabetic line codes are used	Yes			Yes
Transmitting side only	Loss of incoming signal	Yes		Yes	

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

1.4.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally.

1.4.2.2 Deferred maintenance alarm indication generated to signify that performance is deteriorating.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 1.4.2.1 and 1.4.2.2 above, is left to the discretion of each Administration.

1.4.2.3 AIS applied to the line side (see Note 1 and Note 3)

1.4.2.4 AIS applied to the interface side

Note 1 – The equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1 s.

Note 2 – The emission of the AIS in case of "Failure of power feeding" is not required when this action can be activated by detecting the failure "Loss of incoming line signal".

Note 3 – The bit rate of this AIS should be within the tolerance limits defined in § 1.1.

2 Characteristics of digital line systems on coaxial cables

For the parameters, see G.911 § 2.

3 Characteristics of digital line systems on symmetrical pair cables

For the parameters, see G.911 § 2.

4 Characteristics of digital line systems on optical fibre cables

For the parameters, see G.911 § 2.

Reference

[1] CCITT Recommendation *Specification for instrumentation to measure bit-error ratio on digital systems*, Vol. IV, Fascicle IV.4, Rec. O.151.

Recommendation G.917

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 44 736 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *Characteristics of interfaces*

The digital interfaces at 44 736 kbit/s should comply with Recommendation G.703.

1.2 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.2.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.2.2 *Jitter*

1.2.2.1 *Lower limit of maximum tolerable jitter at the input*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.2 *Limit of output jitter*

Note – The need of having this item in the Recommendation and the corresponding value are under study.

1.2.2.3 *Maximum output jitter in absence of input jitter*

Under study.

1.2.2.4 *Jitter transfer function*

Under study.

1.2.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3 *Fault conditions and consequent actions*

Under study.

2 Characteristics of digital line systems on coaxial cables

For the parameters see G.911 § 2.

3 Characteristics of digital line systems on optical fibre cables

For the parameters see G.911 § 2.

Recommendation G.918

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 139 264 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *General features*

1.1.1 *Bit rate*

The digital line section should be able to transmit signals at a nominal bit rate of 139 264 kbit/s with a tolerance of ± 15 parts per million (ppm).

1.1.2 *Special properties*

The digital line section should be bit sequence independent.

1.2 *Characteristics of interfaces*

The digital interfaces at 139 264 kbit/s should comply with Recommendation G.703.

1.3 *Performance standards*

The specifications of the parameters of error performance, maximum output jitter in the absence of input jitter, jitter transfer function and availability will be made, taking into account the length of an homogeneous section of the hypothetical reference digital paths specified in Recommendation G.721.

1.3.1 *Error performance*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.3.2 *Jitter*

1.3.2.1 *Lower limit of maximum tolerable jitter at the input*

The digital line section should be able to tolerate at its input port a digital signal with the electrical characteristics as specified in G.703 but modulated by a sinusoidal jitter having an amplitude/frequency relationship as defined in G.703. The equivalent binary content of the signal with jitter modulation should be a pseudorandom bit sequence of $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.2 *Limit of output jitter*

In all network situations the limit of output jitter should comply with Recommendation G.703.

The equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of length $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.3 *Maximum output jitter in absence of input jitter*

Under study.

The equivalent binary content of the signal to measure the output jitter shall be a pseudorandom bit sequence of length $2^{23} - 1$ bits as defined in Recommendation O.151 [1].

1.3.2.4 *Jitter transfer function*

Under study.

1.3.3 *Availability*

Not yet defined. (This characteristic will be defined according to the results of CCITT studies on network performance.)

1.4 *Fault conditions and consequent actions*

1.4.1 *Fault conditions*

The digital line section at 139 264 kbit/s should detect the following fault conditions:

1.4.1.1 Failure of internal power supply

1.4.1.2 Failure of power feeding of regenerators

1.4.1.3 Error ratio $1 \cdot 10^{-3}$

Note – The criteria for activating and deactivating these alarm indications are under study.

1.4.1.4 Error ratio $1 \cdot 10^{-6}$

1.4.1.5 Loss of incoming line signal

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.6 Loss of line word alignment when alphabetic line codes are used.

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

1.4.1.7 Loss of incoming interface signal

1.4.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 1/G.918.

TABLE 1/G.918

Fault conditions and consequent actions for digital line sections at 139 264 kbit/s

Equipment	Fault conditions	Maintenance Alarms		AIS to	
		Prompt	Deferred	line side	interface side
Line terminal equipment	Failure of internal power supply	Yes		Yes, if practicable	Yes, if practicable
	Failure of power feeding of regenerators	Yes			Yes, if practicable
Receiving side only	Error ratio $1 \cdot 10^{-3}$	Yes			Yes
	Error ratio $1 \cdot 10^{-6}$		Yes		
	Loss of incoming signal	Yes			Yes
	Loss of line word alignment when alphabetic line codes are used	Yes			Yes
Transmitting side only	Loss of incoming signal	Yes		Yes	

Note – A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

1.4.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally.

1.4.2.2 Deferred maintenance alarm indication generated to signify that performance is deteriorating.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 1.4.2.1 and 1.4.2.2 above, is left to the discretion of each Administration.

1.4.2.3 AIS applied to the line side (see Note 1 and Note 3).

1.4.2.4 AIS applied to the interface side.

Note 1 – The equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1 s.

Note 2 – The emission of the AIS in case of "Failure of power feeding" is not required when this action can be activated by detecting the failure "Loss of incoming line signal".

Note 3 – The bit rate of this AIS should be within the tolerance limits defined in § 1.1.

2 Characteristics of digital line systems on coaxial pair cables

For the parameters see G.911 § 2.

3 Characteristics of digital line systems on optical fibre cables

For the parameters see G.911 § 2.

Reference

[1] CCITT Recommendation *Specification for instrumentation to measure bit-error ratio on digital systems*, Vol. IV, Fascicle IV.4, Rec. O.151.

9.2 Digital line transmission systems on cable at nonhierarchical bit rates

Recommendation G.921

DIGITAL LINE SECTIONS AND DIGITAL LINE SYSTEMS ON CABLE AT 3152 kbit/s

(Geneva, 1980)

1 Characteristics of digital line sections

1.1 *Characteristics of interfaces*

The digital interfaces at 3152 kbit/s should comply with the interface specification given in Annex A.

1.2 *Performance standards*

1.2.1 *Error performance*

Under study.

1.2.2 *Jitter*

1.2.2.1 *Lower limit of maximum tolerable jitter at the input*

Under study.

1.2.2.2 *Maximum output jitter*

Under study.

1.2.2.3 *Maximum output jitter in the absence of input jitter*

Under study.

1.2.2.4 *Jitter transfer function*

Under study.

1.2.3 *Availability*

Under study.

1.3 *Fault conditions and consequent actions*

Under study.

2 Characteristics of digital line systems on symmetrical pair cables

For the parameters see G.911, § 2.

3 Characteristics of digital line systems on optical fibre cables

For the parameters see G.911, § 2.

ANNEX A

(to Recommendation G.921)

Interface at 3152 kbit/s

A.1 Interconnection of 3152-kbit/s signals for transmission purposes is accomplished at a digital distribution frame.

A.2 The signal shall have a bit rate of 3152 kbit/s ± 30 ppm.

A.3 One balanced twisted pair shall be used for each direction of transmission. The distribution frame jack connected to a pair bringing signals to the distribution frame is termed the in-jack.

The distribution frame jack connected to a pair carrying signals away from the distribution frame is termed the out-jack.

A.4 Test load impedance shall be 100 ohms, resistive.

A.5 A bipolar (AMI) code shall be used. In order to guarantee adequate timing information, the minimum pulse density taken over any 130 consecutive time slots must be 1 in 8. The design intent is that the long-term pulse density be equal to 0.5. In order to provide adequate jitter performance for systems, timing extracting circuits should have a Q of 1200 ± 200 that is representable by a single tuned network.

A.6 The shape for an isolated pulse measured at either the out- or in-jack shall meet the requirements of Table A-1/G.921. There is no necessity for pulse overshoot for this interface.

A.7 The peak-to-peak voltage within a time slot containing a zero (space) produced by other pulses meeting the specifications of Table A-1/G.921 should not exceed 0.1 of the peak pulse amplitude.

TABLE A-1/G.921

Digital interface at 3152 kbit/s

Location		Digital distribution frame
Bit rate		3152 kbit/s ± 30 ppm
Pair(s) in each direction of transmission		One balanced twisted pair
Code		Bipolar (AMI)
Test load impedance		100 ohms, resistive
Pulse characteristics	Nominal shape	Rectangular
	Nominal amplitude	3.0 volts
	Width (at 50% amplitude)	159 ± 30 ns
	Rise and fall times (20-80% of amplitude)	≤ 50 ns (difference between rise and fall times shall be 0 ± 20 ns)
Signal power (all is signal, measured over 10 MHz bandwidth)		16.53 ± 2 dBm [ratio of (power in + pulses) to (power in − pulses) shall be 0 ± 0.5 dB]

Recommendation G.922

DIGITAL LINE SYSTEM AT 564 992 kbit/s ON COAXIAL PAIRS

(Geneva, 1980)

1 General

This Recommendation concerns the digital line system for the transmission of 4 × 139 264 kbit/s signals on 2.6/9.5 mm coaxial pairs.

The digital line muldex equipment combines the functions of multiplexing the four digital signals at 139 264 kbit/s and of a line transmission equipment at 564 992 kbit/s.

It is intended that this system be compatible with the existing 60-MHz FDM system as recommended in Recommendations G.333 [1] and G.337 [2] (in terms of repeater and remote power feeding spacing, etc.).

With reference to Figure 1/G.922, this Recommendation is presented in three parts:

1) a part for digital line sections at 139 264 kbit/s,

2) a part for multiplexing strategy,

3) a part for digital line systems at 564 992 kbit/s.

2 Characteristics of digital line sections at 139 264 kbit/s

The four digital line sections at 139 264 kbit/s provided by this system should comply with Recommendation G.918.

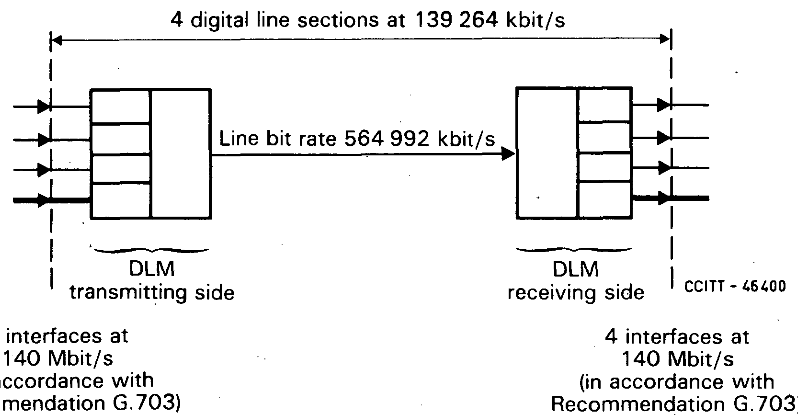


FIGURE 1/G.922

DLM Digital line muldex

3 Digital multiplexing strategy

3.1 *General*

The digital multiplexing strategy is based on the use of positive justification and combines four 139 264 kbit/s tributaries into one composite signal.

3.2 *Bit rate*

The nominal bit rate should be 564 992 kbit/s. The tolerance on that rate should be ± 15 parts per million (15 ppm).

3.3 *Frame structure*

Table 1/G.922 gives:

- the tributary bit rate and the number of tributaries,
- the number of bits per frame,
- the bit numbering scheme,
- the bit assignment,
- the bunched frame alignment signal.

Note – Possible alternative frame structures with the characteristics indicated in Annex B are left for further study.

3.4 *Loss and recovery of frame alignment*

Loss of frame alignment should be assumed to have taken place when four consecutive frame alignment signals have been incorrectly received in their predicted positions.

When frame alignment is assumed to be lost, the frame alignment device should decide that such alignment has effectively been recovered when it detects the presence of three consecutive frame alignment signals.

The frame alignment device, having detected the appearance of a single correct frame alignment signal, should begin a new search for the frame alignment signal when it detects the absence of the frame alignment signal in one of the two following frames.

Note – As it is not strictly necessary to specify the detailed frame alignment strategy, any suitable frame alignment strategy may be used provided the performance achieved is at least as efficient in all respects as that obtained by the above frame alignment strategy.

TABLE 1/G.922

564 992 kbit/s multiplexing frame structure

Tributary bit rate (kbit/s)	139 264
Number of tributaries	4
Frame structure	Bit number
Frame alignment signal (binary content under study) Bits from tributaries	*Set I* 1 to 12 13 to 384
Justification service bits C_{jn} (n = 1 to 5) (see Note) Bits from tributaries	*Sets II to VI* 1 to 4 5 to 384
Remote alarm indication, spare for national use Bits from tributaries available for justification Bits from tributaries	*Set VII* 1 to 4 5 to 8 9 to 384
Frame length Bits per tributary Maximum justification rate per tributary Nominal justification ratio	2688 bits 663 bits 210 190 bit/s 0.4390

Note – C_{jn} indicates the n^{th} justification service bit of the j^{th} tributary.

3.5 *Multiplexing method*

Cyclic bit interleaving in the tributary numbering order and positive justification is recommended. The justification control signal should be distributed and use the C_{jn} bits (n = 1, 2, 3, 4, 5), see Table 1/G.922. Positive justification should be indicated by the signal 11111, no justification by the signal 00000. Majority decision is recommended.

Table 1/G.922 gives the maximum justification rate per tributary and the nominal justification ratio.

3.6 *Jitter*

3.6.1 Jitter transfer characteristics (under study)

3.6.2 Tributary output jitter (under study)

3.7 *Service digits*

The first four bits in Set VII of the pulse frame are available for service functions. The first of these bits is used to indicate a prompt alarm condition, see Table 2/G.922.

Note – A possible solution for scrambler and frame alignment signal is given in Annex A.

4 Characteristics of digital line systems on coaxial pair cables

Most characteristics of digital line systems on 2.6/9.5 mm coaxial pairs are still under study and will be defined in accordance with the studies carried out by the CCITT for digital line systems.

However, the following characteristics have been agreed:

4.1 Bit rate

564 992 kbit/s ± 15 ppm

4.2 *Interface*

The electrical characteristics of an interface at 564 992 kbit/s are not the subject of a Recommendation.

4.3 *Media*

2.6/9.5 mm coaxial pairs

(In accordance with Recommendation G.623 [3].)

4.4 *Nominal repeater spacing*

About 1.5 km.

(In accordance with Recommendation G.337 [2].)

5 Fault conditions and consequent actions

5.1 *Fault conditions*

The digital line system 564 992 kbit/s should detect the following fault conditions:

5.1.1 Failure of internal power supply

5.1.2 Failure of power feeding of regenerators

5.1.3 Error ratio $1 \cdot 10^{-3}$

Note – The criteria for activating and deactivating of these alarm indications are under study.

5.1.4 Error ratio $1 \cdot 10^{-6}$

5.1.5 Loss of incoming line signal

Note – The detection of this fault condition is required only when it does not result in an indication of loss of frame alignment.

5.1.6 Loss of frame alignment

5.1.7 Loss of line word alignment when alphabetic line codes are used

Note – The detection of this fault condition is required only when it does not result in an indication "Error ratio $1 \cdot 10^{-3}$".

5.1.8 Loss of incoming signal on a tributary

5.1.9 Remote alarm indication

5.2 *Consequent actions*

Further to the detection of a fault condition, appropriate actions should be taken as specified in Table 2/G.922.

TABLE 2/G.922

Fault conditions and consequent actions

Equipment	Fault conditions	Maintenance alarms		Alarm indication to the remote line muldex generated	AIS applied, see § 5.2	
		Prompt	Deferred		to all the tributaries	to the relevant time slot of the composite signal
Digital line Muldex	Failure of internal power supply	Yes			Yes, if practicable	
	Failure of power feeding of regenerators	Yes			Yes, if practicable	
Receiving side only of line muldex (See Figure 2/G.901)	Error rate 1 × 10^{-3}	Yes		Yes	Yes	
	Error rate 1 × 10^{-6}		Yes			
	Loss of incoming signal	Yes		Yes	Yes	
	loss of frame alignment	Yes		Yes	Yes	
	Loss of line word alignment when alphabetic line code is used	Yes		Yes	Yes	
	Detection of remote alarm indication					
Transmitting side only of line muldex (See Figure 2/G.901	Loss of incoming signal on a tributary	Yes				Yes

Note - A *Yes* in the table signifies that a certain action should be taken as a consequence of the relevant fault condition. An *open space* in the table signifies that the relevant action should *not* be taken as a consequence of the relevant fault condition, if this condition is the only one present. If more than one fault condition is simultaneously present the relevant action should be taken if, for at least one of the conditions, a *Yes* is defined in relation to this action.

5.2.1 Prompt maintenance alarm indication generated to signify that performance is below acceptable standards and maintenance attention is required locally.

5.2.2 Deferred maintenance alarm indication generated to signify that performance is deteriorating.

Note – The location and provision of any visual and/or audible alarm activated by the alarm indications given in §§ 5.2.1 and 5.2.2 above, is left to the discretion of each Administration.

5.2.3 AIS applied to all the tributaries (see Notes 1 and 2 below).

5.2.4 AIS applied to the relevant time slot of the composite signal (see Note 1 below).

5.2.5 Alarm indication to the remote muldex generated.

Note 1 – The equivalent binary content of the Alarm Indication Signal (AIS) is a continuous stream of 1 s.

Note 2 – The emission of the AIS in case of "Failure of power feeding" is not required when this action can be activated by detecting the failure "Loss of incoming line signal".

Note 3 – The bit rate of this AIS should be within ± 15 ppm of the nominal bit rate.

ANNEX A

(to Recommendation G.922)

A possible solution for scrambler and frame alignment signals for a digital line system at 564 992 kbit/s

A.1 *Reset scrambler*

It is proposed to use a "reset scrambler", i.e. one which is reset at the start of each frame. Advantages of such a scrambler [4] as compared to a free-running or "self-synchronizing" scrambler, are:

- no error multiplication, and
- no necessity to provide additional measures to avoid periodic output signals.

If it is accepted that with an all 1 or all 0 input signal (e.g. with AIS on all four tributaries) the output does not precisely correspond to a $2^n - 1$ pseudorandom sequence but represents an approximately random sequence, fully adequate for timing recovery on the line, a scrambler may be realized (Figure A-1/G.922) which has additional favourable features:

- The scrambler works at ≈ 141 Mbit/s. Four sequences delayed with respect to each other (A0, A2, A5 and A6) are used to scramble the individual tributaries T1 ... T4; the four scrambled signals (c, d, e, f) are then multiplexed.
- Simple circuitry, hence easy realization at the high speed involved, and low power consumption.
- After resetting, the scrambler generates the frame alignment signal.

A.2 *Frame alignment signal*

The frame alignment signal, generated at the start of each pulse frame, is

111110100000

and is thus identical to that of the 139 Mbit/s signal according to Recommendation G.751.

The frame alignment signal will not be imitated by all 0 or all 1 signals even if these occur in any combination in the four tributaries.

ANNEX B

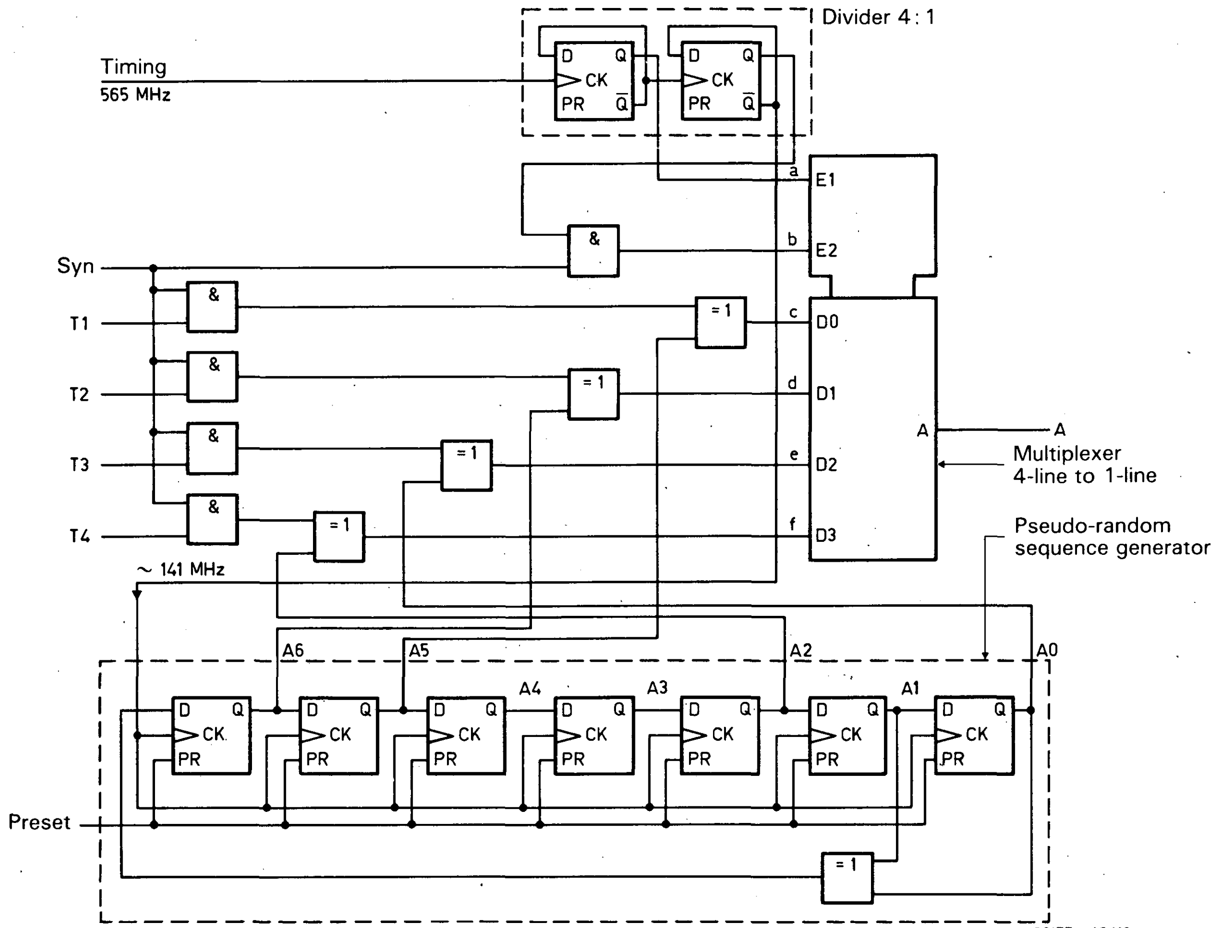
(to Recommendation G.922)

Possible alternative multiplex frame structures

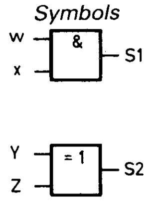
Other multiplex frame structures at 564 992 kbit/s are possible which still retain the same per tributary frame structure as implied by the multiplex frame structure given in Table 1/G.922.

These alternative multiplex frame structures are based on the cyclic interleaving of groups of bits from tributaries and such methods of multiplexing can have implementation advantages when alphabetic line codes such as 6B4T are used. Integration of the multiplex and the line code conversion functions can reduce the speed requirements of the associated circuitry.

Equipments based on these alternative multiplex frame structures, provided that they adopt the same multiplex frame length, the same number of bits per tributary, the same maximum justifications rate and the same nominal justification ratio, are consistent with the network performance offered by equipments using the multiplexing method described in the body of this Recommendation.

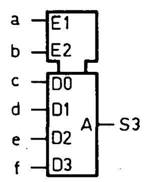


Symbols — *Truth tables*

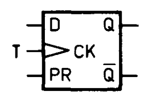


w	x	S1
0	0	0
1	0	0
0	1	0
1	1	1

Y	Z	S2
0	0	0
1	0	1
0	1	1
1	1	0



a	b	S3
0	0	c
1	0	d
0	1	e
1	1	f



PR	T	D	Q
0	X	X	1
1	↑	a	a

Note: T represents the timing signal. The positive-going transition is the active transition.

Time t_n	A6	A5	A4	A3	A2	A1	A0	Preset	Syn	Multiplexed scrambler output signal				A				
0	1	1	1	1	1	1	1	0	0	A5	A6	A5	A6	1	1	1	1	Frame alignment word
1	0	1	1	1	1	1	1	1	0	A5	A6	A5	A6	1	0	1	0	
2	0	0	1	1	1	1	1	1	0	A5	A6	A5	A6	0	0	0	0	
3	0	0	0	1	1	1	1	1	1	A5	A6	A0	A2	T1	T2	$\overline{T3}$	$\overline{T4}$	Scrambled
4	0	0	0	0	1	1	1	1	1	A5	A6	A0	A2	T1	T2	$\overline{T3}$	T4	
5	0	0	0	0	0	1	1	1	1	A5	A6	A0	A2	T1	T2	$\overline{T3}$	T4	
6	0	0	0	0	0	0	1	1	1	A5	A6	A0	A2	T1	T2	$\overline{T3}$	T4	
7	1	0	0	0	0	0	0	1	1	A5	A6	A0	A2	T1	$\overline{T2}$	T3	T4	↓
8	0	1	0	0	0	0	0	1	1	A5	A6	A0	A2	$\overline{T1}$	T2	T3	T4	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮				⋮				

FIGURE A-1/G.922

Reset scrambler and multiplexer

References

[1] CCITT Recommendation *60-MHz systems on standardized 2.6/9.5-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.333.

[2] CCITT Recommendation *General characteristics of systems on 2.6/9.5-mm coaxial cable pairs*, Orange Book, Vol. III-1, Rec. G.337, § 5, ITU, Geneva, 1977.

[3] CCITT Recommendation *Characteristics of 2.6/9.5-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.623.

[4] MÜLLER (H.): Bit sequence independence through scramblers in digital communication systems, *Nachr. techn. Z.*, Vol. 27 (1974), pp. 475 to 479.

9.4 Digital line systems by FDM transmission bearers

Recommendation G.941

DIGITAL LINE SYSTEMS PROVIDED BY FDM TRANSMISSION BEARERS

(Geneva, 1980)

The CCITT,

considering

(a) that there is an urgent need to provide long-haul facilities mainly for nontelephony services (e.g. data, facsimile, visual telephony) for national use and for international interworking, and that these nontelephony services need digital transmission at a low and medium bit rate (e.g. primary and secondary hierarchical levels);

(b) that long-haul digital links begin to be available, but that nevertheless the implementation of these facilities on a general basis will take some time;

(c) that it is possible to use analogue FDM links specified in Recommendation G.211 [1], or the frequencies within or over the bandwidth used by analogue FDM line systems specified in Section 3 of the Series G Recommendations to carry a digital stream, and that some realizations are already available;

recommends

that the digital line systems provided by FDM transmission bearers should comply with the following requirements:

1 General characteristics

Two basic methods can be used for the transmission of digital signals on FDM transmission bearers:

- the first method consists of using either a part or the whole of the band normally employed for FDM systems [Data-in-Voice (DIV)],
- the second method consists of using a band outside the one normally employed for FDM systems [Data-over-Voice (DOV)].

The international interconnection should be performed at digital hierarchical levels using the interfaces specified in Recommendation G.703.

The possibility of defining an analogue interface for international interconnections of DIV systems is under study.

Since these digital line systems (on FDM) transmission bearers could form part of a digital path, their performance standards in terms of error rate, jitter and availability should be in accordance with the relevant Recommendations in Section 9 of the Series G Recommendations concerning digital line sections at the corresponding bit rates.

The systems should be designed in such a way that the quality requirements given in the relevant Recommendations for the analogue circuit are still met.

2 Data-in-Voice systems

2.1 *Characteristics of DIV systems providing 6312-kbit/s digital transmission on a basic mastergroup specified in Recommendation G.211 [1]*

2.1.1 *Digital interface*

The DIV system digital interface should be in accordance with the Recommendation G.703, § 2.

2.1.2 *Analogue interface*

2.1.2.1 *Frequency band*

The DIV signal frequency band should be displaced into the basic mastergroup frequency band specified in Recommendation G.211 [1].

2.1.2.2 *Power level*

The total power in any 4 kHz bandwidth of the DIV signal should be provisionally less than −15 dBm0.

Note – Further study is required for the additional characteristics necessary for international interconnection at the analogue interface.

2.1.3 *Disturbances of the analogue signal by the DIV signal*

The total distributed noise measured in any 3.1-kHz bandwidth should be less than X dBm0p, outside the band 812 to 2044 kHz.

The single tone interferences should be below −73 dBm0 (provisional value).

Note – The value for X is under study.

2.1.4 *DIV system performance*

The performance relating to error rate, jitter and availability should be in accordance with Recommendation G.913.

2.2 *Characteristics of a mastergroup link used to carry the DIV signal*

A Recommendation of the Series H is under study in this connection. This Series H Recommendation will refer to the following characteristics:

2.2.1 *Relative power levels at the mastergroup distribution frames*

2.2.2 *Level stability*

2.2.3 *Attenuation distortion*

2.2.4 *Noise and level of single tone interference*

2.2.5 *Phase jitter*

2.2.6 *Group-delay distortion*

3 Data-over-voice systems

3.1 *Characteristics of DOV systems providing 2048-kbit/s digital transmission on analogue FDM line systems defined by Recommendations G.332 [2], G.334 [3], G.344 [4], G.345 [5] and G.346 [6]*

3.1.1 *Digital interface*

The digital interface of the DOV system should be as specified in Recommendation G.703, § 5.

3.1.2 *Disturbances of the analogue signal by the DOV signal*

The increase to the total distributed noise due to the DOV signal measured in any 4-kHz bandwidth should be less than 750 pW0p for a reference length of 2500 km (less than 0.3 pW0p/km).

Note – The total distributed noise of the line when analogue and DOV signals are present should be below 7500 pW0p for a reference length of 2500 km (less than 3 pW0p/km).

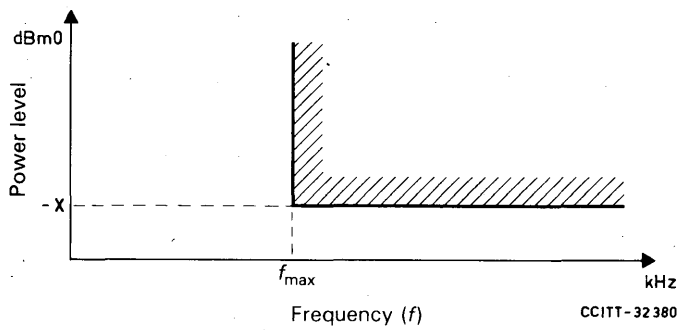
The level of single tone interference should be less than −73 dBm0 (provisional value).

3.1.3 *DOV system performance*

The performance relating to error rate, jitter and availability should be in accordance with Recommendation G.912.

3.2 *Characteristics of the FDM line systems used to carry the DOV signal*

To allow the through-connection of FDM line systems carrying DOV signals, spurious analogue signals should be suppressed before the coupling point, according to the mask given in Figure 1/G.941.



Note – X and f_{max} will be fixed after study, with different values for the different FDM line systems. F_{max} should be higher than the maximum frequency used in different systems, including auxiliary tones.

FIGURE 1/G.941

Power level within 4 kHz bandwidth

References

[1] CCITT Recommendation *Make-up of a carrier link*, Vol. III, Fascicle III.2, Rec. G.211.

[2] CCITT Recommendation *12-MHz systems on standardized 2.6/9.5-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.332.

[3] CCITT Recommendation *18-MHz systems on standardized 2.6/9.5-mm coaxial pairs*, Vol. III, Fascicle III.2, Rec. G.334.

[4] CCITT Recommendation *6-MHz systems on standardized 1.2/4.4-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.344.

[5] CCITT Recommendation *12-MHz systems on standardized 1.2/4.4-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.345.

[6] CCITT Recommendation *18-MHz systems on standardized 1.2/4.4-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.346.

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