PART I

Recommendations G.601 to G.654

CHARACTERISTICS OF TRANSMISSION MEDIA

(Section 6 of the G. Series Recommendations)

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SECTION 6

CHARACTERISTICS OF TRANSMISSION MEDIA

This Section contains the Recommendations on physical transmission media, both for the analogue or digital mode. It does not deal with open-wire lines or radio relays. It relates to VF cables only as physical transmission media in the digital mode.

6.0 General

Recommendation G.601

TERMINOLOGY FOR CABLES

(Geneva, 1980)

1 General terms: repeaters, power feeding, etc.

1001 **repeater**

F: r´ep´eteur

S: repetidor

An equipment essentially including one or several amplifiers and/or *regenerators* , and associated devices, inserted at a point in a transmission medium.

Note — A repeater may operate in one or both directions of transmission.

1002 **analogue repeater; analog repeater**

F: r´ep´eteur analogique

S: repetidor anal´ogico

A *repeater* | or amplifying analogue signals or *digital signals*
| nd capable of other functions, but excluding *regeneration* of *digital signals* .

1003 **regenerative repeater**

F: r´ep´eteur r´eg´en´erateur

S: repetidor regenerativo

A *repeater* | nsuring *regeneration* | f *digital signals* , and capable of other functions.

Note — This definition is different from that given in Recommendation G.701 [1]. At the time when Recommendation G.701 was drafted, a suitable CCITT definition of *repeater* was not available. The ensemble of definitions given here makes it desirable to incorporate the *regenerative repeater* in the family of transmission systems, instead of defining it only as a device, as is the case in Recommendation G.701.

1004 **directly powered (repeater) station**

F: station (de r´ep´eteurs) à alimentation ind´ependante

S: estaci´on (de repetidores) alimentada directamente

A *repeater station* | hich receives its electric power directly from the local mains or from a local generator.

1005 **power feeding (repeater) station**

F: station d'alimentation (de r´ep´eteurs)

S: estaci´on (de repetidores) de telealimentaci´on

A *directly powered repeater station* | hich supplies electric power to other *repeater stations* .

1006 **dependent (repeater) station**

F: station (de r´ep´eteurs) t´el´ealiment´ee

S: estaci´on (de repetidores) telealimentada

A *repeater station* | hich receives its electric power supply from a *power feeding repeater station* .

Note — Electric power may be conveyed to the dependent station either by the physical transmission medium itself, or by conductors in the same cable sheath, or by exterior cables.

1007 **section termination**

F: extr´emit´e de section

S: extremo de secci´on

A point selected conventionally to be the interface between the physical transmission medium and associated equipment such as *repeaters* .

Note — The precise selection of the point to constitute the section termination should take into account associated accessories such as splices, connectors or flexible connecting cables in order to include them, as the case may be, on one side or on both sides of the termination.

1008 **elementary cable section**

F: section ´el´ementaire de c | ble

S: secci´on elemental de cable

All of the physical transmission media and accessories such as splices, connectors or flexible connecting cables included between two consecutive *section terminations* .

1009 **elementary repeatered section**

F: section ´el´ementaire amplifi´ee

S: secci´on elemental con amplificaci´on

In a given direction of transmission an *elementary cable section* | ogether with the immediately following *analogue repeater* , all included between two *section terminations* .

1010 **elementary regenerated section**

F: section ´el´ementaire r´eg´en´er´ee

S: secci´on elemental con regeneraci´on

In a given direction of transmission, an *elementary cable section* | ogether with the immediately following *regenerative repeater* , all included between two *section terminations* .

1011 **take-up factor**

F: facteur de c | blage

S: factor de cableado

Ratio between the value of a linear parameter measured on the length unit of a cable and the value of the same parameter measured on the length unit of a pair of that cable.

The result of cabling (assembly of components and possibly twisting of wires in pairs and then in quads) is that the length of the cable components is greater than that of the axial length of the cable. The take-up factor is the ratio between these two lengths.

1012 Graphic illustration of the use of some terms in § 1.

Figure 1/G.601, p.

Figure 2/G.601, p.

2 Terms concerning cables measurements

2.1 *Use of the word echo, in cable testing only*

2101 **echo**

F: ´echo

S: eco

An electric, acoustic or electromagnetic wave which arrives at a given point, after reflection or indirect propagation, with sufficient magnitude and delay for it to be perceptible at the given point, as a wave distinct from that directly transmitted.

2102 **backward echo**

F: ´echo (vers l’amont)

S: eco hacia atr´as

An *echo* | rriving at a defined point and having a direction of transmission opposite to that of the direct signal.

2103 **forward echo**

F: ´echo vers l’aval; tra | nage

S: eco hacia adelante

An *echo* | rriving at a defined point and having the same direction of transmission as that of the direct signal.

2.2 *Pulse measurements*

2201 **echometric measurement**

F: mesure ´echom´etrique

S: medici´on ecom´etrica

A measurement made by studying the *echo* | hich follows the emission of a signal of limited duration, known as a ‘‘measuring signal’’, with a view to analyzing all the causes of reflections.

2202 **pulse duration**

F: dur´ee d’une impulsion

S: duraci´on del impulso

The interval of time between the first and last instant at which the instantaneous value of a pulse (or of its envelope if a carrier frequency pulse is concerned) reaches a specified fraction of the peak amplitude.

2203 **sine-squared**

F: impulsion en sinus carr´e

S: impulso en seno cuadrado

A unidirectional pulse defined by the expression:

$$y = K \sin^2 (\pi t/2T);\ 0\ t\ \ 2T$$

$$y = 0;\ t < 0 \text{ and } t > 2T$$

where

K is the amplitude

T is the *pulse duration* at half-amplitude

t is the time.

2204 **pulse echo meter**

F: ´echom`etre à impulsions

S: ec´ometro de impulsos

Apparatus designed to take *echometric measurements* | y means of pulses.

2205 **elementary echo**

F: ´echo ´el´ementaire

S: eco elemental

In an *echometric measurement* , the state of the echo in a time interval of a duration comparable to that of the test signal.

2206 **peak amplitude of an elementary echo**

F: amplitude de cr | te d'un ´echo ´el´ementaire

S: amplitud de cresta de un eco elemental

Maximum value of echo amplitude reached in the duration of an *elementary echo* .

2207 **relative amplitude of an elementary echo**

F: amplitude relative d’un écho élémentaire

S: amplitud relativa de un eco elemental

Ratio between the *peak amplitude of an elementary echo* | nd the maximum amplitude of the measuring signal, evaluated at the emission point.

2208 **pulse echo return loss; pulse echo attenuation**

F: affaiblissement d’écho

S: pérdida de retorno para el eco; atenuación de eco

Relative amplitude of an elementary echo | xpressed in transmission units.

2209 **amplitude-corrected echo**

F: écho corrigé en amplitude

S: eco corregido en amplitud

An *echo* | bserved, after processing to carry out at least partial correction of propagation effects.

2210 **amplitude- and phase-corrected echo**

F: écho corrigé en amplitude et phase

S: eco corregido en amplitud y en fase

An *echo* | bserved, after processing has been made to correct the propagation effects on the amplitude and shape of the echo.

2211 **echo curve**

F: courbe d’écho

S: curva de eco

A graphic or oscilloscopic representation of *echo* | mplitude function of time.

Note — The echo may be corrected in amplitude or in amplitude and phase; the curve is then called, as the case may be, ‘‘amplitude-corrected echo curve’’ or ‘‘amplitude- and phase-corrected echo curve’’.

2212 **equivalent resistance error**

F: écart équivalent

S: error de resistencia equivalente

The value of a hypothetical impedance deviation which, if situated at the end of a section of a transmission medium, would produce in an echometric measurement at that end the same reflected energy as all the irregularities of the section.

2213 **corrected equivalent resistance error**

F: ´ecart ´equivalent corrig´e

S: error de resistencia equivalente corregido

Equivalent resistance error | valuated by an echometric measurement comprising echo correction. The correction may be effected in amplitude or in amplitude and phase or according to other criteria (e.g. in energy).

Note — The corrected equivalent resistance error | ay be evaluated in terms of one kilometre, as the ratio ?63$_k$ between corrected equivalent resistance error ?63$_e$ as measured on a cable section, and the square root of the length L of this section, in km.

?63$_k$ = ?63$_e$/√L Ψ × km^{D}lF261^{D}lF]

2.3 *Measurements made with sine-wave signals*

2301 **irregularity reflection coefficient**

F: facteur de r´eflexion sur les irr´egularit´es

S: coeficiente de reflexi´on de las irregularidades

The reflection coefficient measured at one end of a section of a transmission medium, for a specified mode of propagation, under conditions allowing for the elimination of the effects of reflections other than those due to irregularities inherent in the section concerned.

2302 **regularity loss**

F: affaiblissement de l'onde r´efl´echie sur les irr´egularit´es

S: p´erdida de retorno por irregularidades

The expression in transmission units of the modulus of *irregularity reflection coefficient* P_i. Its value in decibels is equal to:

$$A_i = —20 \log_{1\backslash d0} | fIP_{i} |$$

Reference

[1] CCITT Recommendation *Vocabulary of pulse code modulation (PCM) and digital transmission terms* , Vol. III, Rec. G.701.

Recommendation G.602

RELIABILITY AND AVAILABILITY OF ANALOGUE CABLE | fR TRANSMISSION SYSTEMS

AND ASSOCIATED EQUIPMENTS

(Malaga-Torremolinos, 1984)

1 General section

Transmission system: all that is necessary in order to provide an adequately operational transmission path (e.g. 4 kHz channel) between the terminating interfaces. It includes translating equipment, line terminal equipment, line intermediate equipment, cable, power feeding, primary power and standby power supplies and might also include the changeover equipment when automatic protection switching is provided.

2 Definitions

a) **reliability in analogue cable transmission systems**

The reliability of a single unit of an analogue transmission equipment or of a complete transmission system is defined as the probability that this item can perform its required function for a given time interval. One parameter to quantify this reliability is the mean time between failures (MTBF). A failure of the system is considered to occur when there is:

1) complete loss of signal;

2) one in which the pilot level drops by 10 dB below nominal value;

3) when the total unweighted noise power, measured or calculated with an integrating time of 5 ms exceeds 1 million pW (10^6 pW) on the 2500 km hypothetical reference circuit (see Recommendation G.222).

In all instances, this condition must last at least 10 seconds.

This value should be considered as being provisional.

b) **availability in analogue cable transmission systems**

The availability of an analogue transmission system is defined as the ability of the system to be in a state to perform adequately (operating) at a given instant of time or at any instant of time within a given time interval. In this Recommendation, the availability of an analogue transmission system is quantified by the ratio of the time during which the system is operating to a specified total time.

Four factors influencing availability are:

— reliability of the equipment;

— automatic protection switching;

— maintenance procedures;

— cable routing and protection.

In considering the importance to be attached to the individual factors, economic aspects should play an important role.

Note — Experience has shown that in many cases the cable faults are dominating (in the order of 95% of the unavailability time) over the equipment faults and that the length of the line section and the kind of route (running along roads with heavy traffic, etc.) have a decisive influence on the achievable availability values.

3 Objectives

a) *Reliability*

As indicated in the definition of availability, reliability is but one of the factors involved in obtaining an availability objective. Therefore, no specific objective for reliability is recommended.

b) *Availability*

1) *Hypothetical reference circuit (2500 km)*

The objective for the availability of a 2500 km hypothetical reference circuit in one direction should be greater than 99.6% for a one year duration. This takes into account outages for both translating and line equipment and the cable and associated powering equipments. To achieve this objective, appropriate protection switching may be required.

2) *Translating equipment*

The design objective for the availability of translating equipment in the Annex and in Figure A-1/G.602, for a 2500 km hypothetical reference circuit as recommended for the different transmission systems, should be greater than 99.9% measured for a period of one year for one direction of transmission.

3) *Line section*

The design objective for the availability of a 280 km homogeneous section for one direction shall be derived from the overall requirement for the hypothetical reference circuit. The exact value is dependent on the network design.

ANNEX A
(to Recommendation G.602)

Calculation example

Example of Reliability and Availability calculations for a line section in one direction based on the following assumptions:

1) Line repeater MTBF = 2×10^{5} hours (one way);

2) 100 line repeaters in section;

3) Each failure lasts 4 hours;

4) 12 tube cable with 1 | | protection switching.

a) *Reliability* (MTBF)

— 100 repeaters will have failure in $\left(\frac{\times 10^{5}}{00}\right)$ = 2000 hours

b) *Availability* (A)

— This is approximately 4½ failures per year × 4 hours = 18 hours outage per year (0.2%)

— Without protection switching A_1 = 99.8%

Non-available $X_0 = 2 \times 10^{D}$lF261^{3}

— With automatic protection switching: A_2 = [Formula Deleted]

where

N = 5 (number of systems in service)

M = 1 (number of protection systems)

$$A_2 = \left[1 — \frac{!}{!\,|\,!}(2 \times 10^{(em\,3}\,)^{2}\right] \times 100\% = \left[1 = (12 \times 10^{(em\,6}\,)\right] \times 100\% = 99.999\%$$

Note — Calculations are for electronics only and do not take into account cable cuts.

Figure A-1/G.602, p.

6.1 Symmetric cable pairs

Recommendation G.611

CHARACTERISTICS OF SYMMETRIC CABLE PAIRS | fR FOR ANALOGUE TRANSMISSION

(former Recommendation G.321, Geneva, 1974; amended at Geneva, 1980)

1 Cable specification — Examples of the electric characteristics of a star-quad cable designed to provide 12, 24, 36, 48, 60 or 120 carrier telephone channels on each quad pair

1.1 *Types of cable*

Administrations which decide to equip their symmetric pair cable network should, wherever possible, choose those which conform to the types of cable defined below.

New cables laid in the European and North-African international telephone network include unloaded symmetric pairs, designed to be used for 12, 24, 36, 48, 60 or 120 carrier telephone channels on each pair. These pairs are laid up in star quads and all unloaded pairs of the same cable are one of the types whose nominal characteristics are shown in Table 1/G.611.

It is essential that a repeater section crossing a frontier should be of a uniform type throughout its length. When a frontier section is between a large and a small country, the Administration of the larger country should do everything possible to use whichever of the three types has been adopted by the smaller country, so as not to oblige the Administrations of small countries to use sections of international cable of a different type from that of their national cables.

Note 1 — Some Administrations, by paying special attention to crosstalk balance and adopting appro priate repeater spacing, have been able to set up systems with 2 supergroups, in accordance with Recommendation G.322, on paper-insulated symmetric pairs conforming with this present specification.

Note 2 — It is also possible to set up 2 supergroup systems that conform with Recommendation G.322 on pairs of type II | fIbis and type III | fIbis . Type II | fIbis pairs are insulated by polythene and type III | fIbis pairs by styroflex.

H.T. [T1.611]

TABLE 1/G.611

	Type I	Type II	Type II | fIbis	Type III	Type III | fIbis
Diameter of conductors (mm)	0.9	1.2	1.2	1.3	1.3
Effective capacity (nF/km)	33	26.5	21	28	22
{					
Characteristic impedance (Ψ)					
}					
{					
to 60 kHz					
to 120 kHz					
to 240 kHz					
to 550 kHz					
}	153 148 — —	178 174 172 —	206 203 200 198	170 165 163 —	196 193 190 18
{					
Attenuation per unit length at 10 | (deC in dB/km					
}					
{					
to 60 kHz					
to 120 kHz					
to 240 kHz					
to 552 kHz					
}	2.3 3.1 — —	— 2.0 2.9 4.8	— 1.5 2.1 3.1	— 1.8 2.7 4.4	— 1.4 2.0 3.0

Table [T1.611], p.

1.2 *Regularity of factory lengths*

The regularity may be characterized by one or other of the equivalent methods below, the choice of which is left to the Administrations concerned.

1.2.1 *Effective capacity*

The ‘‘effective capacity’’ is measured between the two conductors of the pair, all other cable conductors being connected together and to the sheath.

Ratios of the effective capacity

Type I cable — The average of the effective capacities of all the pairs in any factory length should not differ from the nominal value by more than ± | %.

In any factory length, the difference between any individual value of effective capacity and the average value obtained for this factory length should not exceed ± | .5%; the arithmetic mean of the magnitudes of these differences should not exceed 2.5%.

Types II, II | is, *III and III* | is *cables* — The average effective capacity of any length should not differ by more than ± | % from the nominal value.

In any length, the difference between the effective capacity of any pair and the average capacity for the cable length should not exceed ± | %.

1.2.2 *Impedance* (types II, II | fIbis , III and III | fIbis cables)

The real part of the characteristic impedance of any circuit, measured with a frequency of 120 kHz, should not depart by more than ± | % from the mean value of all the pairs of the first manufacturing batch of each type. This mean value should not depart by more than ± | % from the nominal value at 120 kHz.

The impedance will be measured on the factory lengths using a bridge, the circuits being terminated by an impedance equal to that which is measured by the bridge.

1.3 *Crosstalk*

The quality of the cable from the point of view of crosstalk may be characterized by one or other of the two equivalent methods below, the choice of which is left to the Administrations concerned.

1.3.1 *Direct measurements of crosstalk*

For a factory length of 230 metres the crosstalk between any two side circuits should satisfy the following conditions:

— far-end crosstalk ratio should be greater than 68 dB;

— near-end crosstalk attenuation should be greater than 56 dB.

For cables to be used with 5 groups or 2 supergroups these values should hold up to 240 kHz; and for cables with two groups, up to 120 kHz.

During these measurements, the circuits will be terminated by the real part of the nominal impedance for the frequency considered.

For factory lengths greater than 230 metres, the above limits will be reduced by

$$20 \log_{10} \frac{fIL}{30} \text{ dB,}$$

L being the length in metres. Lengths shorter than 230 metres should satisfy the same conditions as a length of 230 metres.

1.3.2 *Capacity unbalance and mutual inductances*

All the capacity unbalance measurements should be made with an alternating current of 800 Hz. The mutual impedance measurements should be made with an alternating current of 5000 Hz. All the measurements should be made at the ambient temperature, without applying corrections; but in case of dispute, the results obtained at 10 | (deC will be considered as final. All the conductors, other than those under test, should be connected to the cable sheath.

For a factory length of 230 metres the capacity unbalance should not exceed the values given in Table 2/G.611 and the mutual inductances should not exceed the values given in Table 3/G.611. These tables show different values for type I cables in one column, and for types II, II | fIbis , III and III | fIbis in the other.

H.T. [T2.611]

TABLE 2/G.611

Capacity unbalance

{	Type I { Maximum individual reading	Type I {		
{ Capacity unbalance in picofarads: }				
{ between pairs of the same quad }	33	17	125	60
{ beetween pairs of adjacent quads in the same layer }	10	5	60	25
{ between pairs in nonadjacent quads in the same layer }	{			
mean value not specified because all possible combinations are not measured }	20	10		
{ between pairs in quads in adjacent layers }	10	5	60	25
between any pair and earth	100	100	400	400

Note — The limits shown for the mean values do not apply to cables which have four or less quads.

Table [T2.611], p.

H.T. [T3.611]

TABLE 3/G.611

Mutual inductances

{	Type I { Maximum individual reading	Type I {		

{
Mutual inductances in nanohenrys:
}
{
between pairs of the same quad
}
	150	125	600	500

{
between pairs of adjacent quads in the same layer
}
	100	40	400	150

{
between pairs in nonadjacent quads
}
	50	20	350	150

{
between pairs in quads in adjacent layers
}
	100	40	600	250

Note — The limits shown for the mean values do not apply to cables which have four or less quads.

Table [T3.611], p.

For lengths greater than 230 metres, it is necessary to apply the following rules:

The average values from pair to pair given in Tables 2/G.611 and 3/G.611 should be multiplied by the square root of the ratio between the length in question and 230 metres.

All the maximum values, as well as the average values between a pair and earth, should be multiplied by the ratio between the length in question and 230 metres.

Lengths shorter than 230 metres should satisfy the same conditions as the length of 230 metres.

1.4 *Dielectric strength*

When specially requested, cables will have a construction such that the insulation of any cable length should be capable of withstanding, without breakdown, a potential difference specified in each particular case but not exceeding 2000 volts r.m.s., applied for at least 2 seconds between all the conductors connected together and the earthed sheath. The test can be made with a 50-Hz alternating current. The value of the test voltage should not exceed by more than 10% the peak value of a sinusoidal voltage having the same r.m.s. value.

The test can also be carried out using direct current (see [1]). In such a case, the limit for the voltage will be 1.4 times the r.m.s. value of the voltage when using alternating current

1.5 *Insulation resistance*

In a length of cable, the insulation resistance measured between a conductor and all the other conductors connected together, and to the earthed sheath, should not be less than 10 | 00 MΨ-km, the potential difference used being at least 100 volts and not greater than 500 volts. The reading shall be made after electrification for one minute, the temperature being at least 15 | (deC.

2 Specification of a repeater section

2.1 *Maximum attenuation in a repeater section*

The maximum attenuation at the highest frequency transmitted to line of a normal repeater section shall be 41 dB for low-gain systems with 1, 2 or 3 groups and 36 dB for low-gain systems with 4 or 5 groups or 2 supergroups.

2.2 *Crosstalk*

The far-end crosstalk ratio between circuits in the same direction, measured on the repeater sections of a carrier system on unloaded symmetric pairs, terminated at their two ends by impedances equal to their characteristic impedance, should not be less than the values shown below (which allow for the existence of any crosstalk balancing networks).

1) For the classical method of balancing, the repeater section far-end crosstalk ratio for low gain transistorized systems up to 120 channels on type II and III cables (or similar cables) or low-gain 120-channel systems on type II | fIbis or III | fIbis cables should not be less than 69.5 dB.

2) When a ‘‘balancing section’’ comprises several repeater sections, an equivalent result can be obtained from the formula 69.5 — 10 $\log_{1\backslash d0} n$ (dB), where n is the number of repeater sections in the balancing section.

2.3 *Regularity of impedance*

The impedance of any circuit in a repeater section forming part of a carrier system on unloaded symmetric pairs should not differ from the nominal value by more than the values shown below:

± | % (value measured at 60 kHz) for a repeater section forming part of a 12-channel system;

± | % (value measured at 108 kHz) for a repeater section forming part of a 24-channel system;

± | % (value measured at 120 kHz) for a repeater section forming part of a 36- or 48-channel system;

In reference [2], the CCITT does not recommend a formula for general application for tests on mixed dielectrics. However, for tests of telephone cables, the CCITT recommends the use of the factor 1.4 as representative of current commercial practice.

± | %	(value measured at 240 kHz) for a repeater section forming part of a 60-channel system;

± | %	(value measured at 552 kHz) for a repeater section forming part of a 120-channel system.

2.4 *Dielectric strength*

If it is desired to check the dielectric strength of a repeater section after laying, direct current will be applied to the cable at a voltage equal to the specified r.m.s. alternating current test voltage for tests on factory lengths (see § 1.4 above).

2.5 *Insulation resistance*

The insulation resistance measured at the end of the cable between any one conductor and all the other conductors bunched and connected to the earthed sheath (excluding internal repeater station wiring) should not be less than 10 | 00 MΨ-km measured at a potential difference of at least 100 volts and not more than 500 volts. The reading shall be made after electrification for one minute.

References

[1] *Dielectric strength tests* , Blue Book, Vol. III, Part 4, Annex 19, ITU, Geneva, 1965.

[2] *Ibid.* , § 4.

Recommendation G.612

CHARACTERISTICS OF SYMMETRIC CABLE PAIRS DESIGNED FOR THE | fR TRANSMISSION OF

SYSTEMS WITH BIT RATES OF THE ORDER OF 6 TO 34 Mbit/s

(Geneva, 1976; amended at Geneva, 1980)

1 Preamble

This Recommendation relates to symmetric pair cables which have been developed for the transmission of signals with bit rates of the order of 6 to 34 Mbit/s, but they are not ruled out for the transmission of lower or higher bit rates, subject to the use of an appropriate regeneration section; in most cases they can also be used for baseband transmission of videophone or television signals.

These cables fall into two categories, according to whether or not the cable is intended for use in both directions of transmission in the same cable.

2 Parameters to be measured

Those parameters which, for digital system transmission, have to be measured by a particular method or at frequencies different from those defined in Recommendation G.611, are: characteristic impedance, attenuation coefficient, and far-end crosstalk between pairs on the same direction of transmission. If the cable is intended for use with both directions of transmission within the same cable, it is also necessary to measure the near-end crosstalk between pairs intended for different directions of transmission.

2.1 *Characteristic impedance*

The characteristic impedance may be measured:

— either in the sinusoidal mode, when the measured pair will be terminated by an impedance constantly equal to that measured by the bridge, except when the length is sufficient for the measurement result to be independent of the termination impedance;

— or by a pulse echo meter , when the impedance of the pair being measured is compensated by an adjustable balancing network graduated to show the impedance value. The pair being measured is terminated by an identical network.

This method is similar to the one used for coaxial pairs, but with a symmetrical measuring head and networks. The pulse duration is equal to 100 ns; the echo is not corrected.

2.2 *Attenuation coefficient*

The attenuation per km of the pairs is derived from that value to be obtained on an elementary cable section, allowance being made for the tolerance accepted on the length of these sections.

Note — In the case of looped measurement, a check should be carried out to ensure that the near-end crosstalk attenuation between the ends of the circuit being measured is sufficient.

2.3 *Crosstalk*

Crosstalk may be specified either in sinusoidal mode, at a frequency near the timing half-frequency of the system concerned, or in digital mode

2.3.1 *Far-end crosstalk measurement*

The far-end crosstalk measurements are carried out on pairs used in the same direction of transmission at a frequency above about 100 kHz; if this frequency is not the timing half-frequency of the system, the value to be specified will be corrected to the factor 20 $\log_{10} f$

2.3.2 *Near-end crosstalk measurements*

If it is intended to transmit in both directions on the same cable, these measurements are conducted on a prototype length, either in sinusoidal mode or digital mode, between pairs used for opposite directions of transmission.

3 **Description of pairs and cables**

Administrations which decide to use symmetrical pairs to transmit digital signals with a bit rate of the order of 6 to 34 Mbit/s should, wherever possible, choose one of the types of cable described in §§ 3.1 and 3.2 below.

3.1 *Cable designed for use with one cable for each direction of transmission*

3.1.1 The basic characteristics of the pairs are given in Table 1/G.612.

3.1.2 The characteristics of cables constructed with these pairs are given in Table 2/G.612.

3.2 *Cables designed for transmission in both directions in the same cable*

Tables 3/G.612 and 4/G.612 indicate the characteristics of the pairs which make up cable pairs and quad cables respectively.

All these cables consist of bundles protected by one or more copper or aluminium screens, the pairs in each bundle being used for the same direction of transmission. For this reason, near-end crosstalk values relate only to pairs in different bundles.

Note 1 — To make the presentation of Tables 3/G.612 and 4/G.612 uniform, the values of characteristic impedance are given at 1 MHz (real part of Z_1). The ratio between impedance $Z_1 = X_1 - jY_1$ at 1 MHz and impedance $Z_f = X_f - jY_f$ at f MHz is

$$X_f = X_1 - Y_1 + \frac{Y_1}{\sqrt{f}}$$

An example of a digital technique is given in Supplement No. 19.

For symmetrical pair star-quad cables the correction law 20 $\log_{10} f$ is used for pairs of the same quad only up to a certain characteristic frequency, above this frequency the law 40 $\log_{10} f$ must be used.

and $Y_f = Y_1 / \sqrt{f}$

The differencee between the value of the real part of the impedance at 1 MHz and its value at 4 MHz is between 2 and 3 Ψ. At 1 MHz, the imaginary part of the impedance is between 4 and 6 Ψ; for frequencies above about 0.3 MHz, it varies in the inverse ratio to the square root of the frequency.

Note 2 — For the same reason as in Note 1 above, the attenuation value is given at 1 MHz. At a frequency f MHz ($f > 1$), attenuation α_f is related to attenuation α_1 at 1 MHz by the ratio $\alpha_f = \alpha_1 \sqrt{f}$.

Note 3 — The value of far-end crosstalk is reduced to a length of 1000 m by a correction of 10 $\log_{10} L$ if the cable length L being measured is different from 1000 m. The crosstalk values indicated are the minimum limit values for the specification of systems. Where either of the above conditions is not fulfilled, the values are shown between brackets.

H.T. [T1.612]

TABLE 1/G.612

Pair characteristics	Type I cable
Diameter of conductors (mm)	0.64
{ Average mutual capacitance of pairs (nF/km) }	24.2
{ Characteristic impedance (Ψ) | ua) }	178 |
{ Attenuation coefficient at 24 | (deC (dB/km) | ua) }	13.5

a) The attenuation and impedance measurement frequency is 3150 kHz.

Table 1/G.612 [T1.612], p.

H.T. [T2.612]

TABLE 2/G.612

	Set 1 | ua)	Set 2 | ua)
{ Nominal characteristic impedance Z 0 (Ψ) (desired average at 3150 kHz) }	178	
Attenuation and crosstalk { Attenuation at 3150 kHz to 24 | (deC (dB/km) } pair minimum pair maximum { Far-end crosstalk (FEXT) loss at 3150 kHz dB for a 300 m (1000 feet length) } { pair minimum power sum minimum pair-to-pair (0.1% point) }	11.8 14.35 37.5 40.5	11.8 14.6 39.0 40.5
{ DC resistance at 24 | (deC (Ψ/km) } { maximum conductor desired average }	56.8 54.5	
{ Cable average mutual capacitance (nF/km) } { maximum minimum desired average r.m.s. standard deviation (σ) of pairs within a cable (%) }	25.4 23.0 24.2 7	
{ Capacitance unbalance to ground (pF/km) } { maximum pair cable average }	443 164	
DC dielectric strength { between conductors for ARPAP | ub) sheath core and inner aluminium to shield core to inner aluminium and shield } ≥" 1 | 00 V (applied for 1 s) ≥" 20 | 00 V (applied for 3 s) ≥" 5 | 00 V (applied for 3 s) }	{	

a) Two sets of values for attenuation and far-end crosstalk are given. The cable may meet either one of these sets, thus allowing a cable with lower loss to meet a less stringent crosstalk requirement.

b) Aluminium-resin-polythene-aluminium-polythene.

Table 2/G.612 [T2.612], p.

H.T. [T3.612]

TABLE 3/G.612

Cable pairs

Characteristics		Cable type I	II	III	IV	V	
{ Nominal characteristic impedance Z 0 at 1 MHz (Ψ) }		160 |	160 |	140 |	120 |	145 |	
Far-end crosstalk { (minimum values referred to 1000 m) } (dB)	1 MHz					56 |	64 |
	4 MHz		43 | ua)	43 | ua)		44 |	52 |
	17 MHz				40 |	31 |	40 |
{ Near-end crosstalk from 1 to 17 MHz (minimum values, dB) }		119 |	119 |	98 |	116 |	125 |	
{ Nominal attenuation coefficient at 1 MHz | ub) (dB/km at 10 | (deC) }		7.0	9.3	10.5	9.5	5.2	
Nominal capacity (nF/km)		28.5	28.5	31.5	38 |	30 |	
Diameter of conductors (mm)		0.8	0.6	0.65	0.9	1.2	

a) Far-end crosstalk measurements on elementary cable sections for pairs of this type are made in the digital mode only (see Supplement No. 19). The maximum value specified is 30 mV.

b) The real values should make it possible to meet the conditions required for an elementary cable section (Type I: 56 ± 2 dB at 4.2 MHz and 10 | (deC for 4 km; Type II: 56 ± 2 dB at 4.2 MHz and 10 | (deC for 3 km; Type III: below 55 dB at 3.15 MHz for 2.8 km).

Table TAble 3/G.612 [T3.612], p.

H.T. [T4.612]

TABLE 4/G.612

Quad cables

Characteristics	Cable type I	II
{ Nominal characteristic impedance Z 0 at 1 MHz (Ψ) }	165	120
{	Different quads 46 34 31 Same quad { 46 34 c)	{ 56 44 31 {
{ Near-end crosstalk, from 1 to 17 MHz (minimum values, dB) }	125 | ub)	116
{ Nominal attenuation coefficient at 1 MHz (dB/km at l0 | (deC) }	8.8	9.5
Nominal capacity (nF/km)	28	38
Diameter of conductors (mm)	0.65	0.9

a) For 34 Mbit/s transmission over each pair of a star quad, a balancing method is applied to the elementary cable section of 2 km by means of systematic crossings every 500 m, which improves the far-end crosstalk values by at least 15 dB. Hence the values given in this box correspond to 500 m of cable.

b) The value must be above 130 dB in 99% of cases.

c) The transmission of 34 Mbit/s over each pair of a star quad is studied.

Table 4/G.612 [T4.612], p.

CHARACTERISTICS OF SYMMETRIC CABLE PAIRS USABLE WHOLLY FOR THE TRANSMISSION OF DIGITAL SYSTEMS

WITH A BIT RATE OF UP TO 2 Mbits

(Malaga-Torremolinos, 1984)

1 Preamble

This Recommendation deals with cables designed for the transmission of standard digital systems (Recommendations of the G.900 series), although these cables can also be used to transmit digital signals with a lower bit rate and voice frequency signals. The cables described carry signals in both transmission directions simultaneously. The provisions of this Recommendation apply to cables designed to allow for digital operation of all the cable circuits. However, some of the provisions may be used to assess the possibility of (partial or full) digital operation of existing cables.

2 Parameters to be measured

2.1 *Direct current resistance*

The following formula is used to correct the value R_t of direct current resistance measured at t | (deC for 20 | (deC:

$$R_{2\backslash d0} = R_t/(1 + 0.004\,(t - 20))$$

2.2 *Capacitance per unit length*

This is measured at 800 Hz or 1000Hz.

2.3 *Attenuation coefficient*

The value of the attenuation coefficient is obtained either by direct measurement of the attenuation or by calculation on the basis of the mutual capacitance and direct current resistance of the pair. The attenuation coefficient is measured at one frequency only, f_0, near the timing half-frequency.

H.T. [T1.613]

System	Recommendation	f_0
1544 kbit/s	G.951	772 kHz
2048 kbit/s	G.952	1 MHz

Table [T1.613], p.

For cables with polyolefin insulation, the value of the attenuation coefficient at frequency f (for values of f above with a few hundred kHz) can be related to α_0 by the equation $\alpha_f = \alpha_0 \sqrt{\frac{f \mathrm{I} f}{f \mathrm{I} f_0}}$.

The value of the attenuation coefficient measured at t | (deC is corrected for 20 | (deC by the equation:

$$\alpha_{2\backslash d0} = \alpha_t/(1 + 0.002\,(t - 20))$$

2.4 *Characteristic impedance*

2.4.1 *Echometric measurement*

When a pulse echometer is used, the impedance of the pair measured must be compensated by a calibrated balancing network which can be set in steps of about 0.5 Ψ. Pulse duration will be equal to or less than 500 ns. With this method, which is both fast and simple, the value of the end impedance of the pair measured is read off directly on the scale of the balancing network.

2.4.2 *Sinusoidal measurement*

In this case, the pair tested will be terminated across an impedance, which is constantly equal to that measured by the bridge, unless it is long enough for the result of the measurement to be independent of end impedance (as for elementary cable sections).

2.5 *Crosstalk*

Crosstalk can be measured sinusoidally or digitally. The assignment of pairs to the direction of transmission depends on the structure and type of manufacture of the cable.

2.5.1 *Sinusoidal measurement*

2.5.1.1 *Far-end crosstalk*

The measurements are made between pairs assigned to the same direction of transmission, at frequency f_0. If the frequency at which measurement is carried out is not the timing half-frequency, the value is corrected using the $20 \log_{10} f$ law. When the measurement is carried out on a pair of length, L, which is different from the specified reference length L_0, the measured value is corrected using $\sqrt{fIL / L_0}$ when the value is expressed in mV or $10 \log_{10} \frac{fIL}{fIL_0}$ when the value is expressed in dB.

2.5.1.2 *Near-end crosstalk*

The measurements are made between pairs assigned to transmission in opposite directions, at a frequency near the system's timing half-frequency.

2.5.2 *Digital measurement*

By means of digital measurement, it is possible to estimate the total noise on an elementary section, taking account of both near-end and far-end crosstalk. This estimate can be made on the basis of separate near-end and far-end crosstalk measurements on either factory lengths or elementary sections. These measurements can be made either in factory conditions or on installed cables.

2.5.2.1 *Far-end crosstalk*

The measurements are carried out between pairs assigned to the same direction of transmission. When the measurement is carried out on a pair of length, L, which is different from the specified reference length L_0, the measured value is corrected using $\sqrt{fIL / L_0}$ when the value is expressed in mV or $10 \log_{10} (L / L_0)$ when the value is expressed in dB.

2.5.2.2 *Near-end crosstalk*

One advantage of digital measurements is that it is possible to make a direct overall measurement of the total noise on an elementary section if enough generators are available.

The measurements are made between pairs *assigned* | o transmission in opposite directions.

3 Circuit characteristics

These are given in Table 1/G.613.

4 Characteristics of connected cable sections

These are given in Table 2/G.613.

H.T. [1T2.613]

TABLE 1/G.613

Circuit characteristics

|

Characteristics	Type of cable Type I	Type II	Type II *bis*	Type III ****	f)		
Operational bit rate (kbit/s)	2048	2048	2048	2048			
Repeaters gain | *	34 dB						

{
Elements constituting the cable
}
	star quad	pairs	pairs	pairs			

{
Nominal conductor diameter (mm)
}
	0.8	0.7	1	0.6			

{	1 MHz	100	130	130	772 kHz		
{	1 MHz	16	11.5 |)	8.5 |)	15.5	772 kHz	

{
Crosstalk in digital operation
}
{
Total noise voltage (maximum value)
}
	a)
	a)						

{	a)	—	60 d, |)	60 d, |)	a)		
{	a)	—	45 e, |)	45 e, |)	a)		
{		78 ± | |)	772 kHz	Far-end (dB)	1 MHz	64 ± | h)	772 kHz

{
Nominal direct current resistance at 20 | (deC (Ψ/km)
}
		68.6	94.1 b)	46.1 b)	63		

{
Nominal mutual capacitance (nF/km)
}
		50	39	39	44		

Table 1/G.613 [1T2.613], p.

H.T. [2T2.613]

Notes of Table 1/G.613

*

At the present stage the values are given for information.

** Reference value for the numerical data of the cable in question.

***

A standard deviation or margins will be given at a later stage.

**** Cable with diametral screen separating the pairs assigned to the two directions of transmission.

a) To be specified.

b) Maximum value.

c) The specification value for factory controls is calculated to ensure compliance with the characteristics of connected cable.

d) Between pairs of different groups.

e) Between pairs belonging to one and the same group.

f) Other columns will contain the data supplied by administrations.

g) Values given in dB.

h) The value given here depends on the content of the cable. It is the rounded-down mean of a standard deviation of the total production and is therefore not a specification for individual cable lengths.

H.T. [T3.613]

TABLE 2/G.613

Characteristics of connected cable sections

|

Characteristics	Type of cable					
	Type I	Type II	Type II *bis*	Type III	a)	
Operational bit rate (kbit/s)	2048	2048	2048			
{	1 MHz	100	130	130	772 kHz	
{	1 MHz	16	11.5	8.5	772 kHz	
{	b)	40 mV	b)			
{	b)	b)				
{	b)	b)				
{		772 kHz	Far-end (dB)	1 MHz	772 kHz	

* At the present stage the values are given for information.

a) Other columns will contain the data supplied by Administrations.

b) To be specified.

Notes Tableau [2T2.613], p.

H.T. [T3.613]

TABLE 2/G.613

Characteristics of connected cable sections

|

Characteristics	Type of cable					
	Type I	Type II	Type II *bis*	Type III	a)	
Operational bit rate (kbit/s)	2048	2048	2048			
{	1 MHz	100	130	130	772 kHz	
{	1 MHz	16	11.5	8.5	772 kHz	
{	b)	40 mV	b)			
{	b)	b)				
{	b)	b)				
{		772 kHz	Far-end (dB)	1 MHz	772 kHz	

* At the present stage the values are given for information.

a) Other columns will contain the data supplied by Administrations.

b) To be specified.

Table 2/G.613 [T3.613], p.

CHARACTERISTICS OF SYMMETRIC PAIR STAR-QUAD CABLES DESIGNED EARLIER FOR ANALOGUE TRANSMISSION SYSTEMS AND BEING USED NOW FOR DIGITAL SYSTEM TRANSMISSION

AT BIT RATES OF 6 TO 34 Mbit/s

(Melbourne, 1988)

1 Introduction

This Recommendation relates to symmetric pair star-quad cables which have been designed earlier and used to provide 60 or 120 carrier telephone channels of analogue transmission systems on each quad pair. Further, after reconstruction of the line, these cables are used for digital system transmission at bit rates of 6 to 34 Mbit/s. The cables concerned have no screened pairs and quads.

For digital transmission systems with a bit rate of 8 Mbit/s both one-cable and two-cable operations may be used. For systems with a bit rate of 34 Mbit/s two-cable operation is used only.

For digital transmission systems both several, or all cable pairs may be used.

2 Parameters to be measured

All parameters specified in Recommendation G.612, namely characteristic impedance, attenuation coefficient, far-end crosstalk between pairs on the same direction of transmission, and near-end crosstalk between pairs of two different cables intended for different directions of transmission are to be measured. If the cable is intended for use with both directions of transmission it is also necessary to measure the near-end crosstalk between pairs intended for different directions of transmission.

2.1 *Characteristics impedance*

The characteristics impedance is measured according to § 2.1 of Recommendation G.612.

2.2 *Attenuation coefficient*

The attenuation coefficient is measured according to § 2.2 of Recommendation G.612.

2.3 *Crosstalk*

The crosstalk is specified in sinusoidal mode at a frequency near the timing half-frequency of the digital system and/or at other frequencies. Digital mode of measuring may be used also.

2.3.1 *Measurement of far-end crosstalk between pairs of different quads*

The measurement of the far-end crosstalk is carried out on pairs used in the same direction of transmission at a frequency above about 0.1 MHz when a length of cable is L. If the frequency of measurements differs from the timing half-frequency of the digital transmission system the value to be measured will be corrected to the factor $20 \log_{1\backslash d0} f$. The values are corrected to the length of 1000 m by the factor $10 \log_{1\backslash d0} L$.

2.3.2 *Measurement of far-end crosstalk between pairs of the same quad*

This measurement is carried out at a cable length equal to maximum permissible length of regenerator section of digital transmission system with bit rates of 6 to 34 Mbit/s at a frequency above about 1.0 MHz (measurement is carried out for each rate of digital transmission system separately) with systematic component of crosstalk in the same quad compensated. The compensation of systematic crosstalk component is carried out by one of the approximately equivalent transposition patterns (see Figure 1/G.614). When regenerator sections are of less length these methods of falling the elementary cable sections into separate parts and of transposition in quad provide the greater values of the far-end crosstalk between pairs than those values when measurements are carried out at a maximum length of regenerator section.

Figure 1/G.614, p.

2.3.3 *Measurement of near-end crosstalk between pairs of the same or different cables intended for different directions of transmission*

This measurement is carried out either between pairs of the same cable (when one-cable operation is used), or between pairs of two different cables intended for different directions of transmission (when two-cable operation is used). The measurements are carried out both in sinusoidal and digital modes.

3 Cable specification

Administrations which decided to use cables designed earlier and used for analogue carrier systems with up to 120 channels in digital operation at bit rates 6 to 34 Mbit/s are recommended to choose cables with characteristics given in Tables 1/G.614 and 2/G.614.

3.1 *Tables used for digital transmission systems with bit rates of 6 to 8 Mbit/s in one-cable operation*

See Table 1/G.614.

H.T. [T1.614]

TABLE 1/G.614

Characteristics	Requirements		
Types of cable	I (Note 1)	II (Note 1)	III (Note 1)
{ Operational bit rate C, kbit/s }	8448	8448	8448
Line code	HDB-3	HDB-3	HDB-3
Modulation rate, kbaud	8448	8448	8448
{ Tolerate attenuation of regenerator section at a frequency of C/2 when pairs of cable are of maximum use and directions of transmission are set in different quads (maximum permissible value), dB }	23	23	45 (Note 3)
{ Diameter of copper conductor, mm }	1.2	1.2	1.3
{ Previous cable operating range }	HF	HF	AF, HF
Type of insulation	Pl	Pl	Pl, P
Number of star quads	4	7 (Note 2)	3, 4, 8
{ Characteristic impedance at 1 MHz, ohms }	165	165	170
Nominal capacity, nF/km	24.5	24.5	21.0
{ Attenuation coefficient, dB/km at 10 | (deC }			
— at 1 MHz	4.8	4.5	3.7
— at a frequency C/2	10.6	9.7	8.0
{ Near-end crosstalk at a frequency of C/2, dB }			
— mean value	48	50	50
— minimum value	34	34	44
{ Far-end crosstalk between pairs of different quads (minimum value referred to 1,000 m), dB }			
— at 1 MHz	54	54	60
— at a frequency of C/2	42	42	48
{ Far-end crosstalk between pairs of the same quad (minimum value at regenerator section of maximum length), dB }			
— at 1 MHz	60	60	60
— at a frequency of C/2	43	43	48

Note 1 — These characteristics relate to cables with aluminium covering.

Note 2 — Central quad not used for digital system transmission.

Note 3 — Regenerators of the transmission direction B-A installed in midpoint of the section of the opposite direction A-B.

HF High-frequency

AF Audio-frequency

Pl String polysterene

Paper

Table 1/G.614 [T1.164], p.

3.2 *Cables used for digital transmission systems with bit rates of 6 to 34.368 Mbit/s in two-cable operation*

See Table 2/G.614.

H.T. [T2.614]
TABLE 2/G.614

Characteristics	Requirements		
Type of cable	I (Note 1)	II (Note 1)	III (Note 1)
{ Operational bit rate C, kbit/s }	8448	34 | 68	34 | 68
Line code	HDB-3	5B6B	5B6B
Modulation rate, kbaud	8448	41 | 42	41 | 42
{ Attenuation of regenerator section at a frequency of C/2 when all pairs of cable are used (maximum permissible value), dB }	70	85	85
{ Diameter of copper conductor, mm }	1.2	1.2	1.3
Number of star quads	4	4	3. 4. 8
{ Characteristic impedance at 1 MHz, ohms }	165	165	170
Nominal capacity, nF/km	24.5	24.5	21.0
{ Attenuation coefficient, dB/km at 10 | (deC }			
— at 1 MHz	4.8	4.8	3.7
— at a frequency C/2	10.6	24.0	17.0
{ Far-end crosstalk between pairs of different quads (minimum value referred to 1,000 m), dB }			
— at 1 MHz	54	51	60
— at 4 MHz	42	42	48
— at 12 MHz	—	32	30
— at 17 MHz	—	30	26
{ Far-end crosstalk between pairs of the same quad (minimum value at a regenerator section of maximum length), dB }			
— at 1 MHz	42	—	60 (Note 3)
— at 4 MHz	30	33 (Note 2)	48 (Note 3)
— at 12 MHz	—	17 (Note 2)	27 (Note 3)
— at 17 MHz	—	13 (Note 2)	17

(Note 3) *Note 1* — These characteristics relate to cables with aluminium covering.

Note 2 — These values are obtained by means of transposition pattern No. 5 (see Figure 1/G.614) for four cable lengths (0.825 km).

Note 3 — These values are obtained by means of transposition pattern No. 2 (see Figure 1/G.614).

Table 2/G.614 [T2.164], p.

6.2 Land coaxial cable pairs

The coaxial cables described in the following Recommendations of this section 6.2 can be used for different kinds of systems. The following tables illustrate the possible uses of the various pairs.

H.T. [T1.612]
TABLE 1/G.612

Pair characteristics	Type I cable
Diameter of conductors (mm)	0.64
{ Average mutual capacitance of pairs (nF/km) }	24.2
{ Characteristic impedance (Ψ) | ua) }	178 |
{ Attenuation coefficient at 24 | (deC (dB/km) | ua) }	13.5

a) The attenuation and impedance measurement frequency is 3150 kHz.

Table 1 [T1.6.2], p.

H.T. [T2.612]
TABLE 2/G.612

	Set 1 | ua)	Set 2 | ua)
{ Nominal characteristic impedance Z 0 (Ψ) (desired average at 3150 kHz) }	178	
Attenuation and crosstalk { Attenuation at 3150 kHz to 24 | (deC (dB/km) } pair minimum pair maximum	11.8 14.35	11.8 14.6
{ Far-end crosstalk (FEXT) loss at 3150 kHz dB for a 300 m (1000 feet length) } { pair minimum power sum minimum pair-to-pair (0.1% point) }	37.5 40.5	39.0 40.5
{ DC resistance at 24 | (deC (Ψ/km) } { maximum conductor desired average }	56.8 54.5	
{ Cable average mutual capacitance (nF/km) } { maximum minimum desired average r.m.s. standard deviation (σ) of pairs within a cable (%) }	25.4 23.0 24.2 7	
{ Capacitance unbalance to ground (pF/km) } { maximum pair cable average }	443 164	
DC dielectric strength { between conductors for ARPAP | ub) sheath core and inner aluminium to shield core to inner aluminium and shield } ≥" 1 | 00 V (applied for 1 s) ≥" 20 | 00 V (applied for 3 s) ≥" 5 | 00 V (applied for 3 s) }	{	

a) Two sets of values for attenuation and far-end crosstalk are given. The cable may meet either one of these sets, thus allowing a cable with lower loss to meet a less stringent crosstalk requirement.

b) Aluminium-resin-polythene-aluminium-polythene.

Table 2 [T2.6.2], p.

CHARACTERISTICS OF 0.7/2.9 mm COAXIAL CABLE PAIRS

(Geneva, 1976; amended at Geneva, 1980)

Administrations which decide to use for digital transmissions, and possibly also for particular types of analogue transmission, coaxial pairs smaller than the 1.2/4.4-mm coaxial pair should as far as possible choose pairs complying with the specifications given in this Recommendation. The use of these pairs is defined in Tables 1 and 2 given in the introduction to Subsection 6.2.

1 Pair characteristics

1.1 *Electrical characteristics of the coaxial pair*

1.1.1 *Characteristic impedance*

The nominal value of the real part of the characteristic impedance at 1 MHz should be 75 Ψ.

The mean real part of the impedance of a coaxial pair at 1 MHz should not differ from the nominal figure by more than ± | .5 Ψ.

Table 1/G.621 shows the general trend of the variation of the impedance as a function of frequency.

H.T. [T1.621]

TABLE 1/G.621

Mean real part of the impedance measured at various frequencies

Frequency (MHz)	0.2	0.5	1	2 |	5 |	10	20 |	∞
Impedance (Ψ)	77.7	75.9	75	74.2	73.4	73	72.8	72.2

Table 1/G.621 [T1.621], p.

1.1.2 *Attenuation coefficient*

The nominal value of the attenuation coefficient, at 10 | (deC and at 1 MHz, is equal to 8.9 dB/km.

Table 2/G.621 shows the general trend of the variation in attenuation coefficient as a function of frequency at the temperature 10 | (deC.

H.T. [T2.621]

TABLE 2/G.621

Mean values of the attenuation coefficient at various frequencies

Frequency (MHz)	0.2	0.5	1 |	2 |	5 |	10 |	20 |
{ Attenuation coefficient (dB/km) }	4.5	6.5	8.9	12.6	19.8	28.0	39.6

Table 2/G.621 [T2.621], p.

1.2 *Mechanical construction of the coaxial pair*

The pair has the following constitution:

a) nominal diameter of solid-copper wire inner conductor: 0.7 mm;

b) nominal internal diameter of outer conductor: 2.9 mm;

A single bimetallic copper-steel-copper tape may also be used to serve as outer conductor and screen.

c) outer conductor consisting of a copper tape with a thickness of the order of 0.1 mm, laid lengthwise with overlap ;

d) screen consisting of a steel tape with a thickness of the order of 0.1 mm, laid lengthwise with overlap

2 Cable specification (factory lengths of about 500 m)

2.1 *Characteristic impedance*

To check that the value given in § 1.1.1 is met, pulse measurements can be made. The mean real part of the impedance at 1 MHz is to be taken as meaning the resistive component of the impedance at 1 MHz of the network with the best balance against the coaxial pair measured.

2.2 *Impedance regularity*

Routine control measurements of impedance regularity are carried out by means of pulse echometers from one or both ends of the factory lengths. The echo curve should be plotted with correction in amplitude and if possible in amplitude and phase.

Table 3/G.621 shows the various values to be obtained according to the purpose for which the cable is intended.

H.T. [T3.621]

TABLE 3/G.621

Echometric measurement of factory lengths

| ua)

Type of system	Digital		
Bit rate Medium bit rate (6 to 34 Mbit/s) }	{		
Maximum pulse duration	100 ns		
General provisions	Maximum peak	100% 95%	36 dB 39 dB
{	A B	Mean of 3 maximum peaks {	39 dB

a) It is enough to check that one of the two conditions A or B is fulfilled.

Note 1 — The percentage figures given in the table relate to all the pairs of a batch of cables submitted for control or delivered at the same time.

Note 2 — With the construction techniques used so far, systematic faults do not give rise, in steady-state measurements of regularity return loss, to peaks at frequencies below 60 MHz. For this reason, and taking into account the bit rate envisaged, steady-state measurements of regularity return loss do not seem necessary. For other types of construction which might be used in future, supervision of the regularity return loss might be wise; in such cases, the value should be 20 dB from 4 to 60 MHz.

Table 3/G.621 [T3.621], p.

2.3 *Attenuation coefficient*

The attenuation of pairs should be such as to allow compliance with the provisions of § 3.3 below

---

At this stage of manufacture, attenuation measurements are merely prototype measurements.

2.4 *Near-end crosstalk attenuation*

The near-end crosstalk attenuation between coaxial pairs used for different transmission directions, measured in the frequency band 0.5-20 MHz on factory lengths, must be above 135 dB for 100% of measurements.

2.5 *Dielectric strength*

The pair should withstand an a.c. voltage of 1000 r.m.s. at 50 Hz (or a d.c. voltage of 1500 volts) applied for at least 1 minute between the centre and the outer conductor.

If in normal service the outer conductors of the coaxial pairs are not to be earthed, a dielectric strength test must be carried out between the outer conductors and the earthed metal sheath. For this test, an a.c. voltage of at least 2000 volts r.m.s. at 50 Hz or a d.c. voltage of not less than 3000 V will be applied.

2.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V, should not be less than 10 **|** 00 MΨ-km after electrification for one minute at a temperature not lower than 15 **|** (deC. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every factory length.

3 Elementary cable section specification

It will be a matter for agreement between the Administration and the supplier whether tests are to be carried out on all sections or whether some percentage or even a type-approval test alone will be sufficient, especially in the case of measurements which are different to carry out under field conditions.

3.1 *Mean impedance*

The mean real part of the impedance of a coaxial pair at 1 MHz must not differ from the nominal value (as defined in § 1.1.1) by more than 3 Ψ. Measurements should be affected as described in § 2.1.

3.2 *Impedance regularity*

Measurements are effected as described in § 2.2 above. Table 4/G.621 indicates the various values to be obtained according to the purpose for which the cable is intended. Note 1 of § 2.2 remains valid.

H.T. [T4.621]

TABLE 4/G.621

Echometric measurement of elementary cable sections

Type of system	Digital		
Bit rate Medium bit rate (6 to 34 Mbit/s) }	{		
Maximum pulse duration	100 ns		
General provisions	Maximum peak	100% 95%	30 dB 33 dB
{	A B	Mean of 3 maximum peaks {	33 dB

a) It is enough to check that one of the two conditions A or B is fulfilled.

Table 4/G.621 [T4.621], p.

3.3 *Attenuation coefficient*

At 1 MHz, the real attenuation coefficient must not differ from the nominal figure, as defined in § 1.1.1, by more than ± | .4 dB.

Attenuation measured on a cable at an average temperature of *t* | (deC is referred to 10 | (deC by the formula:

α

10

α

t

[Formula Deleted]

The coefficient of the variation in attenuation as a function of temperature k\u(*a is about 1.8 | (mu | 0D lF261 3 per | (deC for frequencies above 2 MHz and about 1.9 | (mu | 0D lF261 3 per | (deC for 1 MHz.

3.4 *Crosstalk*

The near-end crosstalk attenuation between coaxial pairs used for different transmission directions, measured in the frequency band 0.5-20 MHz on 2- and 4-km sections, should be above 130 dB.

3.5 *Dielectric strength*

The pair must withstand a d.c. voltage of at least 1000 V applied during at least 1 minute between the internal and external conductors.

In addition, a test of dielectric strength between the coaxial pair and earth shall be made as described in § 2.5 using a d.c. voltage of at least 2000 V applied for 1 minute.

3.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V should not be less than 5000 MΨ-km after electrification for 1 minute. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every elementary cable section.

Recommendation G.622

CHARACTERISTICS OF 1.2/4.4 mm COAXIAL CABLE PAIRS

(former Recommendation G.342; further amended)

The following Recommendation describes the 1.2/4.4 mm coaxial pair recommended by the CCITT for the international service. The use of this pair is defined in Tables 1 and 2 given in the introduction to Subsection 6.2. When the possibility of television or digital transmission has been envisaged, it is expressly mentioned in each provision.

1 Characteristics of the pair

1.1 *Electrical characteristics of the coaxial pair*

1.1.1 *Characteristic impedance*

The nominal real part of the characteristic impedance is 75 Ψ at 1 MHz.

The tolerance is ± | .5 Ψ for telephony or ± | Ψ for pairs that may be used for television transmissions.

For information, the impedance values in Table 1/G.622 were obtained at various frequencies on coaxial pairs manufactured by different processes.

H.T. [T1.622]

TABLE 1/G.622

Means real part of the characteristic impedance measured at various frequencies

Frequency (MHz)	0.06	0.1	0.2	0.5	1	1.3	4.5	12 |	18 |
Impedance (Ψ)	79.8	78.9	77.4	75.8	75	74.8	74 |	73.6	73.5

Table 1/G.622 [T1.622], p.

–v’6p’

1.1.2 *Attenuation coefficient*

The nominal value of the attenuation coefficient of the pair, at 12 MHz and at 10 | (deC, is 18.0 ± | .4 dB/km.

Table 2/G.622 shows the general trend of the variation of the attenuation coefficient as a function of frequency for all pairs which conform to the present Recommendation.

H.T. [T2.622]

TABLE 2/G.622

Nominal values of the attenuation coefficient at various frequencies

Frequency (MHz)	0. 06	0.1	0.3	0.5	1 |	1.3	4.5	12	18
{ Attenuation coefficient (dB/km) }	1.5	1.8	2.9	3.7	5.3	6.0	11 |	18	22

Table 2/G.622 [T2.622], p.

–v’6p’ The following equation, in which α is expressed in dB/km and *f* in MHz, gives an approximation of the attenuation coefficient from 2 MHz onwards:

$$\alpha = 0.07 + 5.15 \sqrt{f} + 0.005\, f \, .$$

Note — By way of information, Annex A shows the values measured or specified in various countries, with the corresponding deviations or tolerances. In any case, amplifier design must be based on the values measured on the type of cable which will actually be used.

1.1.3 *Attenuation distortion*

The attenuation distortion required in particular for digital transmission is checked by calculating the ratio $\frac{\alpha_{f1}}{\alpha_{f2}}$ between attenuation values α_{f1} and α_{f2} measured at two frequencies f_1 and f_2.

One of the following three limits should be observed:

$\frac{\alpha_{16\,MHz}}{\alpha_{4\,MHz}}$ 2.005

$\frac{\alpha_{24\,MHz}}{\alpha_{6\,MHz}}$ 2.009

These three conditions are equivalent. Accordingly, only one of them is to be used for checking attenuation distortion.

$$\frac{(*a\ 48\ MHz}{(*a\ 12\ MHz}\quad 2.016$$

The attenuation distortion is checked in the factory on a small percentage of factory lengths.

1.2 *Mechanical construction of the coaxial pair*

The nominal dimensions are the following:

— diameter of solid copper centre conductor: 1.2 mm;

— inner diameter of outer conductor: 4.4 mm.

The cylindrical outer conductor is obtained using a copper tape with a thickness of 0.15 or 0.18 mm.

2 Cable specification

2.1 *Characteristic impedance*

To check that the value given in § 1.1.1 above is met, pulse measurements can be made. The real part of impedance at 1 MHz is to be taken as meaning the resistive component of the impedance at 1 MHz of the network with the best balance against the coaxial pair measured.

2.2 *Impedance regularity*

Routine control measurements of impedance regularity are carried out by means of pulse echometers from one or both ends of the factory lengths. The echo curve should be plotted with correction in amplitude and if possible in amplitude and phase. If the equivalent resistance error is measured, it must be corrected. However, for routine measurements, correction may be dispensed with if the test length is so short that the correction is small.

Table 3/G.622 shows the various values to be obtained according to the purpose for which the cable is intended.

H.T. [T3.622]

TABLE 3/G.622

Echometric measurement of factory lengths

Type of system	Analogue	Digital		
Frequency range or bit rate Medium bit rate (6-34 Mbit/s) }	0.06-6 MHz Hight bit rate (140 Mbit/s)	0.3-20 MHz	{	
Maximum pulse duration	100 ns	50 ns	50 ns	10 ns

General provisions	Maximum peak	100% 95%	45 dB 50 dB	48 dB 50 dB	48 dB 50 dB	48 dB 49 dB
{	A B	Mean of 3 maximum peaks Equivalent resistance error	48 dB 1.2 Ψ	51 dB 1.6 Ψ	51 dB 1.6 Ψ	47 dB 2.5Ψ

a) It is enough to check that one of the two conditions A or B is fulfilled.

Note 1 — For 0.06-1.3 MHz analogue systems, the provisions are the same as for 0.06-6 MHz analogue systems.

Note 2 — To detect systematic irregularities, return wave attenuation measurements should be carried out on a small proportion of factory lengths. The limits to be observed are set out in Table 4/G.622.

Note 3 — The percentage figures given in the table relate to all the pairs of a batch of cables submitted for control or delivered at the same time.

Table 3/G.622] + notes [T3.622], p.

H.T. [T4.622]
TABLE 4/G.622
Return wave attenuation on irregularities

Type of system	Digital		
Frequency range or bit rate Medium bit rate (6-34 Mbit/s) }	{ High bit rate (140 Mbit/s)		
{ Percentage of lengths concerned }	about 5%	about 5%	
Frequency band explored	1-40 MHz	20-100 MHz	
Minimum measured value	100% 95%	20 dB 23 dB	20 dB 23 dB

Table 4/G.622 [T4.622], p.

2.3 *Attenuation coefficient*

At this stage of manufacture, attenuation and crosstalk measurements are merely prototype measurements. The attenuation of pairs should be such as to allow compliance with the provision of § 3.3 below

If reference is made to the length measured along a generatrix of the cable sheath, the attenuation coefficient should be multiplied by the take-up factor, the values of which for different numbers of pairs contained in the cable are given as an indication in Table 5/G.622.

H.T. [T5.622]
TABLE 5/G.622
Take-up factor values

Number of pairs in cable Weighted take-up factor, entire cable }	Take-up factor last layer	{
4 or 6		1.002
8		1.003
12-18	1.004	1.003
24	1.005	1.004
48	1.008	1.006

Table 5/G.622 [T5.622], p.

2.4 *Crosstalk*

The crosstalk between pairs should be such as to allow compliance with the provisions of § 3.4 below

2.5 *Dielectric strength*

The pair should withstand an a.c. voltage of 1000 V r.m.s. at 50 Hz (or a d.c. voltage of 1500 V) applied for at least one minute between the centre and outer conductors.

If, in normal use, the outer conductors of the coaxial pair are not earthed, a dielectric strength test is made between the outer conductors and the earthed metallic sheath. The conductors of the auxiliary quads or pairs are connected to the outer conductors of the coaxial pairs or to the sheath, according to the kind of system used for these quads or pairs. Under these conditions, an a.c. voltage of 2000 V r.m.s. or more at 50 Hz will be applied for at least one minute (or a d.c. voltage of 3000 V or more).

Note — The test voltages recommended take account of the normal safety margins applied in the various countries. Polythene insulation, however, might reasonably withstand considerably higher test voltages. In any case, some other dielectric might conceivably be used in the future.

2.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V, should not be less than 5000 MΨ-km after electrification for one minute, at a temperature not lower than 15 | (deC. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on each factory length.

3 Elementary cable section specification

3.1 *End impedance*

The conditions described in §§ 1.1.1 and 2.1 above are applicable.

3.2 *Impedance regularity*

Impedance regularity measurements are carried out from each end of the elementary cable section. Reference should be made to one of the columns in Table 6/G.622, according to the purpose for which the cable is intended.

3.3 *Attenuation coefficient*

At 1 MHz, the real attenuation coefficient must not differ from the nominal figure by more than ± | .2 dB.

Attenuation measured on a cable at an average temperature of *t* | (deC is referred to 10 | (deC by the formula:

$\alpha_{10} = \alpha_t$

[Formula Deleted]

The coefficient k\u(*a of the variation in attenuation with temperature is about 2 × 10 D lF261 3 per °C at frequencies of 500 kHz or more. It increases slightly at lower frequencies (about 2.8 × 10 D lF261 3 per °C at 60 kHz).

3.4 *Crosstalk*

The far-end crosstalk ratio between two coaxial pairs in a cable transmitting in the same direction at any frequency in the band actually transmitted must be not less than the values given in Table 7/G.622.

H.T. [T6.622]

TABLE 6/G.622

Echometric measurement of elementary cable sections
a)

Type of system	Analogue	Digital		
Frequency range or bit rate Medium bit rate (6-34 Mbit/s) }	0.06-6 MHz High bit rate (140 Mbit/s)	0.3-20 MHz	{	
Maximum pulse duration	200 ns	100 ns	100 ns	50 ns

General provisions	Maximum peak	100% 95%	42 dB 46 dB	42 dB 46 dB	42 dB 46 dB	40 dB 44 dB	
{		{ 45 dB 48 dB { 2.5	45 dB 48 dB 2.5	43 dB 46 dB 3.5	Equivalent resistance error C	Uncorrected (Ψ)	1.8

a) It is enough to check that one of the three conditions A, B or C is fulfilled.

Note 1 — Notes 1 and 2 to Table 3/G.622 still hold good. However, for 0.06 to 1.3 MHz analogue systems, the provisions of column 0.06 to 6 MHz apply, but the pulse duration may attain 400 ns for elementary cable sections longer than 4 km.

Note 2 — Measurements using sine-wave signals on elementary cable sections are unnecessary unless there are serious grounds for believing that systematic irregularities may have been introduced during the laying or installation of the cable. In such cases, the measurement results should not be less than 20 dB.

Tableau 6/G.622 [T6.622], p.

H.T. [T7.622]

TABLE 7/G.622

Minimum far-end crosstalk ratio between two 1.2/4.4 mm coaxial pairs

Length of the section (km)	{ Without phase inversion	{
8	87	—
6	89	80
4	93	—
3	95	83
2	99	—

TABLEAU 7/G.622 [T7.622], p.

There is no need to specify a near-end crosstalk ratio when the former limits are chosen for the far-end crosstalk ratio.

When phase inversion is used, the near-end crosstalk ratio for pairs transmitting in opposite directions must be at least 84 dB for a section about 6 km long, and 87 dB for a section about 3 km long.

Note — These limits enable a far-end crosstalk ratio of 65 dB to be obtained on the worst homogenous 280-km section, assuming that for the frequencies in question only far-end crosstalk due to the cable is to be considered ratio as a function of the distance approximately follows a 20 dB/decade law for distances below a limit distance L_1 and a 10 dB/decade law for distances above L_1. The values depend on a number of factors, mainly the system used, the type of cable and the considered frequency. A value of 30 km appears suitable in most cases, although values of L_1 ranging from a few kilometers to 30 kilometers have been observed in practice, ensuring the consistency of the limits in Table 7/G.622 with the 65 dB limit on a 280 km section.

3.5 *Dielectric strength*

The pair must withstand a d.c. voltage of at least 1000 V applied during at least one minute between the inner and the outer conductors.

In addition, a test of dielectric strength between the coaxial pair and earth shall be made as described in § 2.5, using a d.c. voltage of at least 2000 V applied for one minute.

Note — The recommended test voltages take account of the normal safety margins applied in the various countries. Polythene insulation, however, might reasonably withstand considerably higher test voltages. In any case, some other dielectric might conceivably be used in the future.

3.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V, should not be less than 5000 MΨ-km after electrification for one minute. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every elementary cable section.

ANNEX A

(to Recommendation G.622)

Examples of attenuation coefficient measured or specified in some countries

(Values given as an indication)

H.T. [T8.622]

TABLE A-1/G.622

Values measured on a type of pair whose outer conductor is 0.15 mm thick

Frequency (MHz)	0.060	0.1	0.3	0.5	1	4	12	18	52
Attenuation (dB/km)	1.54	1.85	2.89	3.67	5.21	10.4	18.0	22.0	37.5
Tolerance (dB/km)	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.2	±0.2	±0.5
Temperature coefficient	0.0028	0.0026	0.0024	0.00225	0.0020	0.0020	0.0020	0.0020	0.0020

Table A-1/G.622 [T8.622], p.

In practice it is possible to forget the influence of line

equipment on intelligible crosstalk, but this is only true for low frequencies of the band (less than 300 kHz).

H.T. [T9.622]

TABLE A-2/G.622

Values specified in certain countries for a type of pair whose outer conductor is 0.18 mm thick

Frequency (MHz)	60	100	200	300	500	700	1000	1300	4500
Specific attenuation (dB/km)	1.49	1.80	2.42	2.91	3.73	4.43	5.30	6.05	11.2
Tolerance (dB/km)	±0.1	±0.1	a)	a)	a)	a)	±0.2	±0.2	±0.2

a) Not specified.

Table A-2/G.622 [T9.622], p.

Recommendation G.623

CHARACTERISTICS OF 2.6/9.5 mm COAXIAL CABLE PAIRS

(former Recommendation G.331; further amended)

1 Pair characteristics

It is necessary to have throughout the international network types of coaxial pairs having the same electrical characteristics, in order to enable transmission systems to operate on any cable meeting the specifications of this Recommendation. The use of these pairs is defined by Tables 1/G.623 and 2/G.623 given in the introduction to § 6.2.

1.1 *Electrical characteristics of the coaxial pair*

1.1.1 *Characteristic impedance*

The characteristic impedance of the coaxial pair follows a well-defined law depending on frequency given by:

$$Z = 74.4 \left[1 + \frac{.0123}{\sqrt{f \;|}} (1 - j) \right] \Psi$$

where f | is the frequency measured in MHz

The figure of 74.4 Ψ (impedance at infinite frequency) is subject to a tolerance of ± | Ψ.

1.1.2 *Attenuation coefficient*

The nominal attenuation coefficient of the coaxial pair at a frequency of 60 MHz and a temperature of 10 | (deC should be within the limits of 18.00 ± 0.3 dB/km

This formula is equivalent to $Z = 74.4 + (0.92/\sqrt{f \;|}\,)\,(l - j)$ Ψ. If this latter formula is used, a correcting factor should be applied to the tolerance indicated in the text.

For internal reasons, some Administrations considered it advantageous to use pairs of larger dimensions, with smaller attenuation, making it possible to use longer repeater sections (2 km). Cables manufactured by assembly of these pairs may be regarded as meeting the requirements of this Recommendation for 60-MHz systems provided the electrical characteristics of the repeater sections built up with these cables comply with this Recommendation and provided the line equipments are exactly the same as those used with the cables referred to in this Recommendation. The French Administration's

The rate of the variation of the attenuation with frequency, for a nominal value of 18.00 dB/km at 60 MHz, is indicated in Table 1/G.623.

3.7/13.5-mm pairs described in [1] fall within this category.

H.T. [T1.623]
TABLE 1/G.623
Nominal attenuation coefficient at various frequencies

Frequency (MHz)	0.06	0.3	1 |	4 |	12 |	20 |	40 |	60 |	150 |	300 |
Attenuation (dB/km)	0.59	1.27	2.32	4.62	8.01	10.35	14.67	18.00	28.6	40.7

Table 1/G.623 [T1.623], p.

The following equation, in which α is expressed in dB/km and f | in MHz, gives an approximaion of the attenuation coefficient from 1 MHz onwards:

$$\alpha = 0.01 + 2.3 \sqrt{f} + 0.003 f$$

Note — In designing amplifiers, the values measured on the cable to be used must be taken as reference.

1.1.3 *Attenuation coefficient tolerances — Attenuation distortion*

To guarantee proper adaptation between the coaxial pair and the transmission equipment, in addition to the tolerances at frequency 60 MHz, set at ± | .3 dB/km, it is also necessary to establish the limits of attenuation distortion according to frequency.

Table 2/G.623 gives the nominal values and tolerances of the quantity δ_f | (in mB | (mu | m^{D}lF261^{1} | (mu | Hz^{D}lF261$^{1/2}$)

$$\delta_f = \frac{\alpha_{60}}{\sqrt{60}} - \frac{\alpha_f}{\sqrt{f}}$$

at various frequencies (f in MHz).

H.T. [T2.623]
TABLE 2/G.623
Nominal values and tolerances of the quantity δ

characterizing attenuation distortion at various frequencies

Frequency (MHz)	4 |	12	20 |	40 |	60
Nominal value	1.1	1	0.8	0.4	0
Tolerances	±1.5	±1.1	±0.8	±0.4	±0

Table 2/G.623 [T2.623], p.

To check the attenuation distortion beyond 60 MHz, which is necessary in particular for digital transmission, it is necessary to calculate the ratio between the attenuation values measured at the frequencies of 240 MHz and 60 MHz (after eliminating any peaks). The limit to be observed is:

$$\frac{\alpha_{240\ MHz}}{\alpha_{60\ MHz}} \quad 2.045$$

The attenuation distortion is checked in the factory on a small percentage of factory lengths.

1.2 *Mechanical construction of coaxial pairs*

a) The inner conductor is a solid copper wire 2.6 mm in diameter.

b) The insulation is such that the permittivity of the combination of gas and low-loss solid dielectric material is low enough to meet the requirements of this specification.

c) The outer conductor consists of a copper tape 0.25-mm thick formed into a cylinder of internal diameter 9.5 mm around the insulation.

d) For reasons of crosstalk, the outer conductor should be surrounded by soft steel tapes.

Another form of construction having the same electrical characteristics but with an inner copper conductor of 2.8-mm diameter and an aluminium outer conductor of 10.2-mm internal diameter is used by some Administrations. This type of construction is described in detail in Annex A.

2 Cable specification

2.1 *Characteristic impedance*

To check that the value given in § 1.1.1 above is met, either sine-wave signal measurements or pulse measurements can be made.

For sine-wave signal measurements, the check is often made in terms of the smooth impedance/frequency curve.

For pulse measurements, a sine-squared pulse having a half-amplitude duration of less than 100 ns should be used. One may either balance the impedance against a variable reference impedance or measure the reflection coefficient against a fixed reference standard.

2.2 *Impedance regularity*

Routine control measurements of impedance regularity are carried out by means of pulse echometers from one or both ends of the factory lengths. The echo curve should be plotted with correction in amplitude and if possible in amplitude and phase. If the equivalent error is measured, it must be corrected. However, for routine measurements, correction may be dispensed with if the test length is so short that the correction is small.

Table 3/G.623 shows the various values to be obtained, according to the purpose for which the cable is intended.

Note 1 — For 0.06-6 MHz analogue systems, the provisions are the same as for 0.3-20 MHz analogue systems.

Note 2 — To detect systematic irregularities, return wave attenuation measurements should be carried out on a small proportion of fabricator lengths. The limits to be observed are given in Table 4/G.623.

Note 3 — The percentage figures given in the tables relate to all the pairs of a batch of cables submitted for control or delivered at the same time.

H.T. [T3.623]
TABLE 3/G.623
Echometric measurement of factory lengths

Type of system	Analogue	Digital		
Frequency range or bit rate Very high bit rate (565 Mbit/s) }	0.3-20 MHz	4-70 MHz	Hight bit rate (140 Mbit/s)	{
Maximum pulse duration 10 ns **| fR↑a↑)** } 10 ns **| fR↑a↑)** }	50 ns { 10 ns | ua)	{		

General provisions	Maximum peak	100% 56 dB	50 dB 54 dB | ub)	{ 54 dB | ub)			
{	A { B Equivalent resistance error 0.6 Ψ 0.8 Ψ 0.8 Ψ	Mean of 3 maximum peaks { 1 | Ψ 1.2 Ψ 1.6 Ψ	53 dB 1 | Ψ 1.2 Ψ 1.6 Ψ	{			

Table 3/G.623 [T3.623], p.

H.T. [T4.623]

TABLE 4/G.623

Measurement of factory lengths using sine-wave signals

Type of system	Analogue	Digital		
Frequency range or bite rate	0.3-20 MHz	4-70 MHz	High | ud)	Very high
{ *Return wave attenuation on irregularities* }				
{ Percentage of lengths concerned }	none	about 5%	about 5%	about 5%
Frequency band explored		4-62 MHz	20-100 MHz	62-500 MHz

Minimum measured value	100% 38 dB	35 dB	30 dB	20 dB	95%
{ *Mean return power in a 10-MHz band* (Transmission of television signals in the 60-MHz system) }					
Frequency band concerned	None	52-62 MHz			
Mean power return coefficient	L = 250 m 40 dB	41 dB	35 dB	28 dB	L > 500 m

Notes to Tables 3/G.623 and 4/G.623

a) If investigations or definition studies show that measurements with shorter pulse durations are required, the duration of 2 ns will be adopted.

b) Provided that no more than one value between 48-54 dB is encountered on one and the same coaxial pair of an elementary cable section.

c) It is enough to check that one of the two conditions A or B is fulfilled.

d) The provisions for 4-70 MHz analogue systems are certainly adequate. However, much lower values have also been proposed. Agreement should be reached on the values to be specified and the frequency band to be explored (4-100 MHz or 62-500 MHz).

Table 4/G.623 + notes [T4.623], p.

2.3 *Attenuation coefficient*

At this stage of manufacture, attenuation and crosstalk measurements are merely prototype measurements. The attenuation of pairs should be such as to allow of compliance with the provisions of § 3.3 below

If reference is made to the length measured along a generation of the cable sheath, the linear attenuation coefficient should be multiplied by the take-up factor, the values of which are given as an indication in Table 5/G.623.

H.T. [T5.623]
TABLE 5/G.623
Take-up factor values

Number of pairs in cable Take-up factor, last layer } Weighted take-up factor, entire cable }	{ {	
4 or 6		1.003
8		1.005
12	1.009	1.007
18 or 20	1.012	1.010

Table 5.623 [T5.623], p.

2.4 *Crosstalk*

The crosstalk between pairs should be such as to allow of compliance with provisions of § 3.4 below

2.5 *Dielectric strength*

The pair should withstand for one minute an a.c. voltage of 2000 V r.m.s. at 50 Hz (or 3000 V d.c.) applied between the centre conductor and the outer conductor connected to the sheath. This dielectric strength test should be made on each factory length.

2.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V, should not be less than 5000 MΨ-km after electrification for one minute at a temperature not lower than 15 | (deC. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on each factory length.

3 Elementary cable section specification

The Administration and the supplier must agree on whether tests are to be carried out on all sections or whether some percentage or even a type-approval test alone will be sufficient, especially in the case of measurements which are difficult to carry out under field conditions.

3.1 *End impedance*

The conditions described in §§ 1.1.1 and 2.1 above are applicable.

3.2 *Impedance regularity*

Impedance regularity measurements are carried out from each end of the elementary cable section. Reference should be made to one of the columns in Table 6/G.623, according to the purpose for which the cable is intended.

Note 1 — Notes 1 and 3 to § 2.2 in connection with Table 3/G.623 still hold good. However, for 0.06-6 MHz analogue systems, the provisions of column 0.3-20 MHz apply, but the pulse duration may attain 200 ns for elementary cable sections longer than 5 km.

Note 2 — Measurements using sine-wave signals on elementary cable sections are unnecessary unless there are serious grounds for believing that systematic irregularities may have been introduced during the laying or installation of the cable. In such cases, the measurement results should not be less than 33 dB for the 4-62 MHz band.

3.3 *Attenuation coefficient*

For a cable of any given manufacture with a nominal attenuation coefficient defined by the limits given in § 1.1.2 above, the difference between the maximum and minimum attenuation coefficient values measured at 60 MHz on the coaxial pairs of all elementary sections of 1.5 km must be below 0.4 dB/km (referred to 10 **|** (deC).

Attenuation measured on a cable at an average temperature of *t* **|** (deC is referred to 10 **|** (deC by the formula:

$$\alpha$$

$$\pm 10 \alpha$$

$$t$$

[Formula Deleted]

H.T. [T6.623]

TABLE 6/G.623

Echometric measurement of elementary cable sections

Type of system	Analogue	Digital		
Type of system Very high bit rate (565 Mbit/s) }	0.3-20 MHz	4-70 MHz	High bit rate (140 Mbit/s)	{
Maximum pulse duration	50 ns	10 ns	10 ns | uc)	10 ns | ua)

		100%	50 dB	46 dB	{	
General provisions	Maximum peak	95%	50 dB	{		

{		{ 49 dB 52 dB { 2 |	{ 2 |	2 |	C	Uncorrected (Ψ)	1 |

a) If investigations or definition studies show that measurements with shorter pulse durations are required, the duration of 2 ns will be adopted.

b) It is enough to check that one of the three conditions A, B or C is fulfilled.

c) As long as there does not exist an echometer with impulses of 10 ns capable to explore half a repeater section, the measurement will be done with 50 ns impulses.

Tableau 6/G.623 [T6.623], p.

3.4 *Crosstalk*

The far-end crosstalk ratio between two coaxial pairs of a cable at any frequency in the band transmitted should be at least equal to the values listed in Table 7/G.623.

H.T. [T7.623]
TABLE 7/G.623

Lengths (km) Far-end crosstalk radio (dB) }	Frequency band (MHz)	{
9 | 85 **| fR↑a↑)** }	0.06-4.3	{
4.5	0.3-12.5	94 | ua)
1.5	4-62	130 **| fR↑a↑)**

a) If the cable operates both in the 0.3-12 MHz frequency band and the lower frequency band with longer repeater sections, the value of the far-end crosstalk should be increased by a few decibels to frequencies higher than 300 kHz to allow for the differences in levels across some points of the cable. A limit of 100 dB suffices.

Table 7/G.623 [T7623] p.

With cables operating at 60 MHz, the near-end crosstalk attenuation at 60 MHz between pairs transmitted in opposite directions should be at least 140 dB. No limit is fixed for other systems, previous studies having shown that the near-end crosstalk ratio under service conditions was greater than the far-end crosstalk ratio. These values include the contribution of accessories which are associated to elementary cable section, such as flexible cords and coaxial connector.

Note 1 — The values given for cables operating at 60 MHz are derived from general considerations on crosstalk between sound-programme circuits given in Recommendation J.18 [2]. These values are easy to obtain, although in the present state of the art it is difficult to test them with ordinary measuring equipments.

Note 2 — The values given for cables operating at 12 MHz or less suffice for telephone transmission. For sound-programme circuit transmission, this value must be increased to 105 dB, a value which is easily obtained with all types of cable at frequencies above 300 kHz.

Note 3 — These limits enable at far-end crosstalk ratio of 65 dB to be obtained on the worst homogeneous 280-km section, assuming that for the frequencies in question only far-end crosstalk due to the cable is to be considered the minimum far-end crosstalk ratio as a function of the distance approximately follows a 20 dB/decade law for distances below a limit distance L_1 and a 10 dB/decade law for distances above L_1. The value of L_1 depends on a number of factors, mainly the system used, the type of cable and the considered frequency. A value of 30 km appears suitable in most cases, although values of L_1 ranging from a few kilometers to 30 kilometres have been observed in practice, ensuring the consistency of the limits in Table 7/G.623 with a 65 dB limit on a 280 km section.

3.5 *Dielectric strength*

The pair should withstand for one minute a d.c. voltage of 2000 V applied between the centre conductor and the outer conductor connected to the sheath. This dielectric strength test should be made on each elementary cable section on completion of laying.

3.6 *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 V, should not be less than 5000 MΨ-km after electrification for one minute; the measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every section.

In practice, it is possible to forget the influence of line equipments on intelligible crosstalk, but this is only true for low frequencies of the band (less than 300 kHz).

ANNEX A

(to Recommendation G.623)

Description of a
copper-aluminium coaxial pair having the same

electrical characteristics as the 2.6/9.5-mm copper coaxial pair

The constitution of this copper-aluminium coaxial pair is as follows:

— The centre conductor is a solid copper wire 2.8 mm in diameter.

— The insulation is such that the permittivity of the combination of gas and low-loss solid dielectric material is low enough to meet the requirements of this Recommendation.

— The outer conductor consists of an aluminium tape 0.7-mm thick formed into a cylinder of internal diameter 10.2 mm around the insulation and welded longitudinally.

Such coaxial pairs can be jointed with each other or with 2.6/9.5-mm copper pairs easily and reliably. They meet with all the electrical characteristics of this Recommendation. In particular, the values of far-end crosstalk of § 3.4 of the text are obtained between pairs transmitting in the same direction.

References

[1] Annex 2 to CCITT Question 17/XV, Green Book, Vol. III.3, ITU, Geneva, 1973.

[2] CCITT Recommendation *Crosstalk in sound-programme circuits set up on carrier systems* , Vol. III, Rec. J.18.

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