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CHARACTERISTICS OF 2.6/9.5 mm COAXIAL CABLE PAIRS

ITU-T Recommendation G.623

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation G.623 was published in Fascicle III.3 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

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

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:

$$Z = 74.4 \left[1 + \frac{0.0123}{\sqrt{f}} (1 - j) \right] \Omega$$

where *f* is the frequency measured in MHz[1)]. There is therefore no point in specifying values at all frequencies.

The figure of 74.4 Ω (impedance at infinite frequency) is subject to a tolerance of ± 1 Ω.

1.1.2 *Attenuation coefficient*

The nominal attenuation coefficient of the coaxial pair at a frequency of 60 MHz and a temperature of 10 °C should be within the limits of 18.00 ± 0.3 dB/km[2)].

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.

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

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1) This formula is equivalent to $Z = 74.4 + (0.92 / \sqrt{f})(1 - j)\Omega$. If this latter formula is used, a correcting factor should be applied to the tolerance indicated in the text.

2) 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 3.7/13.5-mm pairs described in [1] fall within this category.

The following equation, in which α is expressed in dB/km and f in MHz, gives an approximation 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 ± 0.3 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 · km^{-1} · MHz$^{-1/2}$)

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

at various frequencies (f in MHz).

TABLE 2/G.623

Nominal values and tolerances of the quantity δ_f

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

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:

$$\frac{\alpha_{240\ \mathrm{MHz}}}{\alpha_{60\ \mathrm{MHz}}} \leqslant 2.045$$

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.

TABLE 3/G.623

Echometric measurement of factory lengths

Type of system				Analogue		Digital	
Frequency range or bit rate				0.3-20 MHz	4-70 MHz	High bit rate (140 Mbit/s)	Very high bit rate (565 Mbit/s)
Maximum pulse duration				50 ns	10 ns	10 ns	10 ns [a)]
General provisions	Maximum peak		100%	50 dB	48 dB	48 dB	
			95%	56 dB	54 dB [b)]	54 dB [b)]	
Additional optional provisions[c)]	A	Mean of 3 maximum peaks		53 dB	51 dB	51 dB	
	B	Equivalent resistance error	L < 300m 300 ≤ L ≤ 500m L > 500m	0.6 Ω 0.8 Ω 0.8Ω	1 Ω 1.2 Ω 1.6 Ω	1 Ω 1.2 Ω 1.6 Ω	

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 [d)]	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%		35 dB	30 dB	20 dB
	95%		38 dB		
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		41 dB	35 dB	28 dB
	L > 500m		40 dB		

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).

2.3 *Attenuation coefficient*

The attenuation of pairs should be such as to allow of compliance with the provisions of § 3.3 below[3)].
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.

3) At this stage of manufacture, attenuation and crosstalk measurements are merely prototype measurements.

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

2.4 *Crosstalk*

The crosstalk between pairs should be such as to allow of compliance with provisions of § 3.4 below [3)].

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 MΩ-km after electrification for one minute at a temperature not lower than 15 °C. 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 °C).

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

$$\alpha_{10} = \alpha_t \frac{1}{1 + k_\alpha (t - 10)}$$

TABLE 6/G.623

Echometric measurement of elementary cable sections

Type of system				Analogue		Digital	
Type of system				0.3-20 MHz	4-70 MHz	High bit rate (140 Mbit/s)	Very high bit rate (565 Mbit/s)
Maximum pulse duration				50 ns	10 ns	10 ns[c]	10 ns[a]
General provisions	Maximum peak	100%		50 dB	46 dB	46 dB	46 dB
		95%			50 dB	50 dB	50 dB
Additional optional provisions[b]		A	Mean of 3 maximum peaks. Uncorrected maximum	51 dB 54 dB	49 dB 52 dB	49 dB 52 dB	49 dB 52 dB
	Equivalent resistance error	B	Energy corrected ($\Omega \cdot km^{-1/2}$)	0.8	2	2	2
		C	Uncorrected (Ω)	1	1.5	1.5	1.5

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.

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.

TABLE 7/G.623

Lengths (km)	Frequency band (MHz)	Far-end crosstalk radio (dB)
9	0.06-4.3	85
4.5	0.3-12.5	94[a)]
1.5	4-62	130

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.

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[4)]. When there is no phase inversion, it is assumed that the variation in 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 MΩ-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.

4) 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.