BS EN 50290-2-1:2005

Communication cables —

Part 2-1: Common design rules and construction

The European Standard EN 50290-2-1:2005 has the status of a British Standard

ICS 33.120.10

British Standards

National foreword

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The UK participation in its preparation was entrusted to Technical Committee EPL/46, Communication cables, wires and waveguides, R.F. connectors and accessories for communication and signalling, which has the responsibility to:

— aid enquirers to understand the text;

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— monitor related international and European developments and promulgate them in the UK.

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Communication cables
Part 2-1: Common design rules and construction

Câbles de communication
Partie 2-1: Règles de conception communes et construction

Kommunikationskabel
Teil 2-1: Allgemeine Entwurf- und Konstruktionsregeln

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 50290-2-1:2005 E

Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 46X, Communication cables.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50290-2-1 on 2004-10-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2005-10-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2007-10-01

This European Standard has been prepared under the European Mandate M/212 given to CENELEC by the European Commission and the European Free Trade Association.

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Contents

Introduction

EN 50290-2-1 series gives directly or by reference all common requirements for communication cables.

It is completed by generic, sectional, family and detail specifications, as appropriate, to describe in a detailed manner each type of cables with its specific characteristics.

EN 50290, which is the basic reference standard for communication cables, consists of the following parts:

- Part 1-1 General
- Part 1-2 Definitions
- Part 2-1 Common design rules and construction
- Part 2-1X Materials
- Part 3 Quality assessment
- Part 4-1 Environmental conditions and safety aspects
- Part 4-2 Guide for use

The test methods are described in the basic reference standard EN 50289, Communication cables - Specifications for test methods, which consists of the following parts:

- Part 1-X Electrical test methods
- Part 2-X Transmission and optical test methods
- Part 3-X Mechanical test methods
- Part 4-X Environmental test methods

1 Scope

This European Standard harmonises the standardisation of symmetrical, coaxial and optical cables used for the infrastructure of communication, multimedia and control networks. Most of the cables covered by this European Standard are primarily intended to be used in IT networks. However, they can also be used for other applications with the exception of those which presume a direct connection to the mains electricity supply.

EN 50290-2-1 gives the common rules for the design and construction of symmetrical, coaxial and optical cables used for the infrastructure of communication and control networks.

It is to be used in conjunction with EN 50290-1-1 and is completed by generic, sectional, family and detail specifications, as appropriate, to describe in a detailed manner each type of cable with its specific characteristics.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50290-1-2	Communication cables - Part 1-2: Definitions
EN 50290-2-23	Part 2-23: Materials - PE insulation
EN 50290-2-24	Part 2-24: Materials - PE sheathing
EN 50290-2-25	Part 2-25: Materials - Polypropylene insulation compounds
EN 50290-2-26	Part 2-26: Materials - Halogen free flame retardant insulation compounds
EN 50290-2-27	Part 2-27: Materials - Halogen free flame retardant thermoplastic sheathing compounds
IEC 60304	Standard colours for insulation for low-frequency cables and wires
IEC 60028	International standard of resistance for copper
IEC 60793-1	Optical fibres - Part 1: Generic specification.

3 Definitions

For the purpose of this standard, the definitions given in EN 50290-1-2 apply.

4 Common design rules

4.1 Materials

4.1.1 Conductor materials

4.1.1.1 Wires and inner conductors

The construction and material of wires or inner conductor shall be specified in the relevant specification.

The conductor shall be either solid or stranded annealed copper. The conductivity of the copper shall be in accordance with IEC 60028.

Alternatively, the conductor shall consist of copper-clad steel. The layer of copper cladding shall be continuous, and shall adhere to the steel; the cross-section shall be circular, such that the maximum resistance of the clad conductor shall not exceed that given for copper conductor, in accordance with IEC 60028, by more than a factor of 4,8, 3,5 and 2,8, respectively, for 21 % (minimum), 30 %, and 40 % nominal conductivity grade copper-clad steel. The percentage elongation at break, when tested in accordance with test methods given in 9.7 shall be not less than 1 %. The minimum tensile strength shall be 827 N/mm², 792 N/mm², 760 N/mm² for 21 %, 30 %, and 40 % grade, respectively.

Alternatively, the conductor shall consist of copper clad aluminium. The layer of copper cladding shall be continuous, and shall adhere to the aluminium, the cross section shall be circular, such that the maximum resistance of the clad conductor shall not exceed that given for copper conductor, in accordance with IEC 60028, by more than a factor of 1.8. The percentage elongation at break, when tested in accordance with test methods given in 9.6 shall not be less than 1 %.

Conductor joints made after the last drawing operation are not allowed.

The stranded conductor shall consist of wires circular in section and assembled, without insulation between them, by concentric stranding or bunching.

The individual wires of the solid or stranded conductor may be plain or metal-coated.

4.1.1.2 Outer conductor or screen

The construction and material of the outer conductor and/or screen shall be specified in the detail specification.

The outer conductor or screen may be

a) a single or double braid of plain or metal coated annealed copper wire. Joints in the braiding wires shall be soldered, twisted or woven-in and there shall be no joint in the complete braid. The braid shall be evenly applied. The braid angle and the filling factor shall be specified in the detail specification,

b) a copper or aluminium tape formed round the core as a continuous and closed screen with a sufficient overlap bonded or not bonded as specified in the detail specification,

c) a high permeability alloy tape, helically wound with overlap,

d) a gas-tight tube of copper or aluminium material (i.e. extruded, welded smooth or corrugated),

e) a layer of metal foil or metallised film applied with a sufficient overlap bonded or not bonded, covered with a copper braid as in item a) above. When the metal foil or the film is in copper, the braid shall be in copper. When the metal foil or the film is in aluminium, the braid shall be in aluminium or tinned copper. The braid shall always be in contact with metal,

f) a screen as described in d) with two layers of bi-directional helically wound wires instead of braid,

g) any combination of these.

4.1.2 Optical fibres

Optical fibres shall be uniform in quality and their characteristics shall meet the requirements of IEC 60793-2-XX.

4.1.3 Taping / Fillers

Tapes and/or fillers may be used to achieve a circular cross section of the cable, and/or to prevent moisture ingress and/or to achieve the required electrical, mechanical and environmental performance. They usually consist of plastic, fibreglass, aromatic polyamide, or swellable material depending upon the intended use.

The relevant specification shall give details of the taping and fillers to be used.

4.1.4 Insulating and sheathing materials

The insulation and outer sheath of the cable shall be of a suitable material as specified in the relevant cable specification.

It may be solid, cellular, or composite (e.g. foam skin, plastic/metal composite).

Unless otherwise specified, plastic materials for sheath and insulation shall comply with the relevant part of EN 50290-2-XX.

The insulation and sheath shall have appropriate mechanical characteristics before and after ageing within the temperature limits to which it may be exposed to normal use.

4.1.5 Messenger wires

4.1.5.1 Design

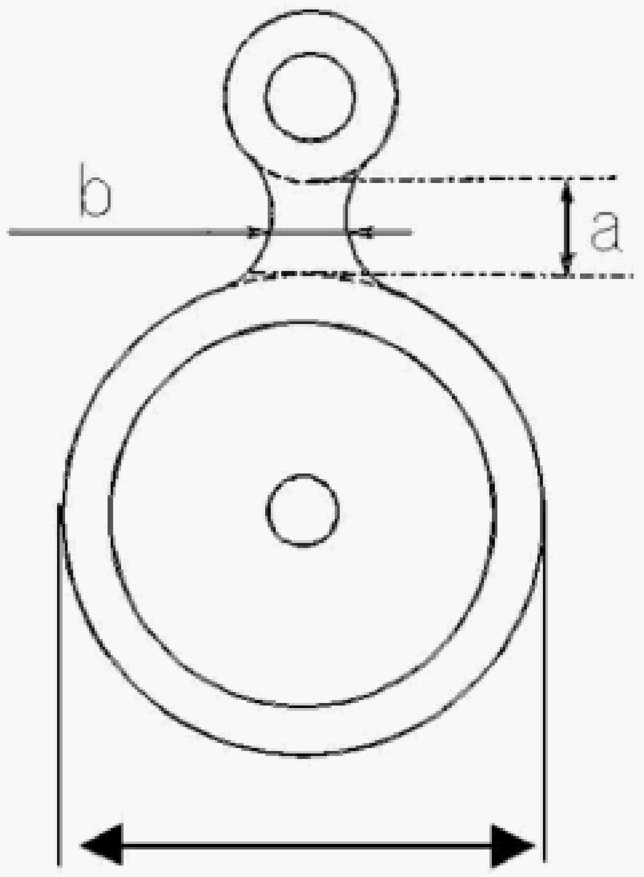
This standard specifies requirements for aerial messenger wires.

Messenger wires shall consist of either a strand (wires twisted together with a uniform lay) or a single wire. Messenger wire may consist of metallic or non-metallic materials.

In case of metallic material, the material used shall consist of either aluminium alloy or steel which may be galvanised. Interstices between the stranded wires may be bituminised as an available option.

Unless otherwise specified in the relevant detail specification, wires in the outer layer of strands shall have a left-hand lay (S strand) and in case of strands with more than seven wires, the lay direction shall alternate for each successive layer.

In the case of a Figure 8-shaped design as shown below, unless otherwise specified in the detail specification, the height (a) and the thickness (b) of the web should be in accordance with Table 1.



Outer diameter of the cable

Table 1

Web dimension in mm			
(a)		(b)	
Min.	Max.	Min.	Max.
3	5	2	4

4.1.5.2 Information to be supplied

The following information shall be given in the relevant detail specification.

- strand and wire diameter — mm;
- cross section — mm²;
- nominal overall messenger diameter and tolerances — mm;
- approximate mass — kg/km;
- breaking load — kN;
- effective modulus of elasticity — kN/ mm²;
- coefficient of linear expansion — 1/°C.
- wire material

4.1.6 Armour

Where additional tensile strength or protection from external damage is required, armouring shall be provided.

Examples of armour include:

- steel tapes;
- steel wires;
- re-inforced glass fibre;
- corrugated steel;
- aramid yarns;
- and any combination of them.

The relevant cable specification shall give details of the armour construction and materials to be used.

4.2 Cable make-up

4.2.1 General design

Communication cables shall be essentially round or flat. They can be formed as

- single element of pair/quad, coaxial or optical fibre cable,
- multi-element of pairs/quads, coaxial or optical fibre cable,
- a combination of two or more of these elements (hybrid cables).

Each of the elements shall comply with the relevant generic and sectional specifications.

The direction of lay may be right (Z) or left (S) hand and may be changed at intervals throughout the length of the cable (SZ). The use of fillers is optional. Different conductors coaxial and optical fibre elements may be insulated or sheathed with different materials.

Although any standardised conductor diameter, within the range given in the generic and sectional specification, may be used, the acceptable dimension for the intended connector or termination hardware shall be taken into account.

When optical fibre elements are assembled with other electrical conductors in a common layer, they shall be cabled with the same direction and lay length as the electrical conductors.

Internal or external electromagnetic behaviour of the cable can require a common screen or individual screens or a combination of them. The screens shall be described only in terms of their electromagnetic performance (coupling attenuation/screening attenuation for frequency above 30 MHz and transfer impedance for frequency below 30 MHz).

To help the design of connectors and connecting terminations information about the design of screens should be given in the relevant cable specification.

4.2.2 Sheathing

A cable sheath shall consist of a continuous outer covering consisting of a material complying with the requirements specified in EN 50290-2-XX. The sheath shall be uniform and shall not have any defects that are visible with normal or corrected vision without magnification.

The sheath shall be applied to fit closely to the cable core. In the case of screened cables, the sheath shall not adhere to the screen except when it is intentionally bonded to it.

4.2.3 Marking

Marking may be required by local regulations (e.g. CE marking), systems specifications or by agreement between customers and suppliers.

5 Register of symbols used

Symbol	Designation	Unit
α	Total attenuation per unit length, 20 °C	dB/m
α_T	Total attenuation per unit length, $T \neq 20$ °C	dB/m
α_x	Attenuation due to element *x*, 20 °C	dB/m
β_x	Braid angle of element *x*	° (degree)
γ_x	Density of the material of element *x*	g/cm^3
δ_x	Loss angle of the material of element *x*	rad
ε_x	Relative dielectric permittivity of the material of element *x*	–
χ_x	Conductivity of the material of element *x*, 20 °C	m/Ωmm^2
σ_x	Thermal resistivity of the material of element *x*	K·m/W
B_x	Braid coverage concerning element *x*	–
C_o	Velocity of propagation in free space	m/s
C_x	Capacitance of element *x*, per unit length	pF/m
D_x	Outer diameter of individual wires or element *x*	mm
D_{xe}	Electrical effective diameter of element *x*	mm
D_{xm}	Mean diameter of element *x*	mm
E_2	Maximum permissible voltage gradient of dielectric (peak value)	kV/mm
F	Frequency	MHz
H_x	Coating thickness concerning element *x*	mm
k_x, k_{xy}	Calculation factors according to Tables 2.1 and 2.2	–
L_x	Braid lay length concerning element *x*	mm
M	Total weight of cable per unit length	g/m
M_x	Weight of element *x*	g/m
N_1	Number of stranded wires of inner conductors	–
N_x	Number of wires to each spindle concerning braid *x*	–
N_x	Number of spindles in the braid concerning element *x*	–
P_{40}	Maximum permissible input power, ambient temperature 40 °C	W
P_T	Maximum permissible input power, ambient temperature $T \neq 40$ °C	W
P_d	Maximum permissible dissipation power per unit length	W/m
Q_x	Filling factor of braid concerning element *x*	–
R_x	DC resistance of conductive element *x*, per unit length	Ω/m
	and insulation resistance of insulating element *x* respectively	MΩ.km
S_x	Nominal thickness of element *x*	mm
$S_{xmin.}$	Minimal thickness of element *x*	mm
T_x	Temperature of element *x*	°C
T_a	Ambient temperature	°C
U_t	Test voltage (50 Hz), rounded r.m.s. value	kV
U_{tc}	Test voltage (50 Hz), calculated r.m.s. value	kV
U_d	Discharge test voltage, r.m.s. value	kV
U_o	Maximum permissible operating voltage, rounded r.m.s. value	kV
U_{oc}	Maximum permissible operating voltage, calculated r.m.s. value	kV
v_r	Velocity ratio	–
Z_o	Characteristic impedance, nominal value	Ω

Numbering of construction elements:

1 inner conductor;

2 dielectric;

3 outer conductor;

4 sheath;

5 medium between outer conductor and screen;

6 screen;

7 medium between first and second screen;

8 second screen;

etc.

Table 2 – Example of use of kx factor

Symbol	Designation	Unit
k_2	Factor dependent on inner conductor concerning the voltage gradient in the dielectric	–
k_4	Thermal dissipation constant of sheath surface in air	$W/m^2K^{1,25}$

Table 3 – Example of use of kxy factor

Factor	Construction element concerned			
	1	3	6	8
Coating factor	k_{1c}	k_{3c}		
Stranding or braiding factor:				
– concerning attenuation	k_{1a}	k_{3a}		
– concerning d.c. resistance and weight	k_{1r}	k_{3r}	k_{6r}	k_{8r}
Ratio between overall diameter and diameter of individual wires	k_{1d}			
Effective diameter factor concerning characteristic impedance	k_{1z}			

6 Material constants

6.1 Table of material constants relating to dielectric and sheath and their values for different materials

Table 4 - Table of plastic material constants

Symbol	Designation	Unit	Value for [a]										
			Solid PE	Semi-air-spaced PE	Cellular [b] PE			PTFE	FEP	Cellular [b] FEP	ETFE	PFA	PVC
2	Permittivity of dielectric	–	2,28	1,4	1,3	1,5	1,7	2,1	2,1	1,5	2,6	2,1	4 to 9
Tan 2	Dissipation factor of dielectric	–	$2,5 \times 10^{-4}$	$2,5 \times 10^{-4}$	4×10^{-4}	6×10^{-4}	6×10^{-4}	[c]	[f]	$1,2 \times 10^{-3}$	[e]	[e]	5×10^{-2}
E_2	Maximum permissible voltage gradient of dielectric	kV/mm	10	2	2	3	4	10	10	4	[e]	[e]	6
2, 4	Density of dielectric or sheath	g/cm³	0,93	0,36	0,28	0,44	0,58	2,2	2,2	0,90	1,7	2,2	1,4 [b]
2, 4	Thermal resistivity of dielectric of sheath	K × m/W	3,5	[e]	15	9	6	4,4	5,0	[e]	4,4	4,5	7,0
T_1	Maximum permissible operating temperature	°C	80/70 [d]	85/70 [d]	70	70	70	250	200 [g]	200 [g]	150 [g]	200 [g]	70

Key

[a] PE = Polyethylene
PTFE = Polytetrafluoroethylene
FEP = fluorinated ethylene propylene
EFTE = Ethylenetetrafluoroethylene
PFA = Perfluoroalcoxylalkane
PVC = Polyvinylchloride

[b] Typical value(s)

[c]

Frequency MHz	Tan 2
1	1×10^{-4}
10^1	$1,5 \times 10^{-4}$
10^2	$2,5 \times 10^{-4}$
10^3	$4,3 \times 10^{-4}$
10^4	2×10^{-4}

[d] 80 °C: high density material
70 °C: other density material

[e] Under consideration

[f]

Frequency MHz	Tan 2
1	4×10^{-4}
10^1	4×10^{-4}
10^2	8×10^{-4}
10^3	10×10^{-4}
2×10^3	10×10^{-4}
10^4	7×10^{-4}

[g] In the case of silvered inner and outer conductors only.

6.2 Tables of material constants relating to conductors

Table 5 – Conductivity (at 20 °C) and density

Conductor	Conductivity (χ) m/Ωmm²	Density (γ) g/cm³
Copper	58	8,9
Aluminium	35	2,7
Tin	8,3	7,3
Silver	61	10,5
Copper clad steel 21 %	[a]	8,06
Copper clad steel 30 %	[a]	8,15
Copper clad steel 40 %	[a]	8,20

[a] According to 4.1.1.1.

Table 6 – Coating factor [a]

Conductor	Symbol	Value
Bare copper wire	k_{1c} and k_{3c}	1
Silvered copper wire		1
Tinned copper wire		Table 7
Copper clad steel wire		Table 8

[a] RF resistance of coated wire in relation to bare copper wire, dependent on frequency and coating thickness.

Table 7 - Tinned copper wire

$h_1\sqrt{f}$ or $h_3\sqrt{f}$	k_{1c} or k_{3c}
0,01	1,01
0,02	1,03
0,03	1,06
0,04	1,11
0,06	1,25
0,08	1,44
0,10	1,67
0,12	1,91
0,15	2,24
0,18	2,46
0,20	2,60
≥ 0,25	2,70

Table 8 – Copper clad steel wire

$h_1\sqrt{f}$	k_{1c} [a]
0,005	11,04
0,010	6,06
0,015	4,16
0,020	3,17
0,025	2,57
0,030	2,16
0,035	1,87
0,040	1,65
0,050	1,35
0,060	1,16
0,070	1,04
0,080	1,00

[a] Assumptions relating to steel:
χ = 8 m/Ωmm2;
relative permeability, μr = 200.

6.3 Construction constants

6.3.1 Table of construction constants relating to inner conductor

Table 9 – Constants relating to inner conductor

Symbol	Designation	Value versus number of strands N_1			
		1	7	12	19
k_{1r}	Stranding factor for d.c. resistance and weight	1,00	1,03	1,03	1,03
k_{1a}	Standing factor for attenuation	1,00	1,25	1,25	1,25
k_{1z}	Effective diameter factor	1,00	0,94	0,96	0,98
k_{1d}	Ratio between overall diameter and diameter of individual wires	1,00	3,02	4,16	5,00
k_2	Voltage gradient factor	1,00	0,90	0,90	0,90

6.3.2 Table of construction constants relating to braided outer conductors and screens

Table 10 – Constants relating to braids

Braid angle β_3; β_6	$\frac{L_3}{D_{3m}}$; $\frac{L_6}{D_{6m}}$	k_{3r}; k_{6r}
20°	8,63	1,06
25°	6,74	1,10
30°	5,44	1,15
35°	4,49	1,22
40°	3,74	1,30
45°	3,14	1,41

Definitions:

$$k_{3r} = \sqrt{1 + \left(\pi D_{3m} / L_3\right)^2} = \frac{1}{\cos \beta_3}$$

$$k_{6r} = \sqrt{1 + \left(\pi D_{6m} / L_6\right)^2} = \frac{1}{\cos \beta_6}$$

6.4 Braid wire dimensions

Table of braid wire dimensions of outer conductor and screen

Table 11 – Braid wire dimensions

Nominal outer diameter of dielectric (D_2) mm	Nominal diameter of braid wire (d_3, d_6) mm	
	Single braid	Double braid

0,87 and 1,5	0,09–0,11	–
2,95, 3,7, 4,8 and 6,4	0,13–0,15	0,13–0,15
7,25, 9,8 and 11,5	0,18–0,20	0,16–0,18
17,3	0,24–0,26	0,18–0,20

6.5 Attenuation factors

Table 12 – Factor relating to calculation of attenuation

Symbol	Designation	Feature	Value
k_{1a}	Attenuation due to inner conductor	Solid wire Stranded wire	1,0 1,25
		Tinned copper wires	See Table 7 see Table 8
k_{1c}		Copper clad steel wire	
k_{3a}	Attenuation due to outer conductor	Tubular outer conductor Braided outer conductor	1,0 2,0 [a]
k_{3c}		Braid wires tinned copper	See Table 7

[a] Rough approximation (in absence of a reliable theory).

6.6 Maximum permissible input power/ Current carrying capacity

6.6.1 Coaxial cables

The method used to calculate the tabulated current carrying capacities is a thermodynamic model of a cable installed indoors in air and considers the heat flow from the inner and outer conductor through the dielectric and jacket materials. It assumes that the conductors carrying current reach an operating temperature of 65 °C based on the cables ability to dissipate heat.

This temperature was chosen to substantially minimise the possibility of accelerated thermal ageing of the dielectric and jacket materials. System designers are encouraged to consider the effect of this operating temperature on conductor resistance (R), voltage drop (IR) and power consumption ($I^2 R$).

When calculating the current carrying capacities of coaxial cables the worst case condition is typically considered. Since indoor cables do not benefit from cooling from wind, it is assumed that cables installed indoors or in enclosed areas represent the worst case scenario.

Current carrying capacities can be calculated by solving the following simultaneous equations:

$$I = \sqrt{\frac{t_c - t_s}{(R_{ic} - R_{eoc}) * (R_{th})}}$$

$$I = \frac{0{,}182 * \varepsilon * D^{0.75} * (t_s - t_a)^{1,25} - D * (t_s - t_a)}{(R_{ic} - R_{eoc}) * (n)}$$

The D.C. current carrying capacities calculated from these general equations are considered to represent current flowing in both the centre and outer conductors of a coaxial cable.

In the equations given above, R_{eoc} is the effective increase in centre conductor resistance due to the effects of the outer conductor and is calculated as follows:

$$\frac{R \quad R}{-}$$

$$R_{eoc} = \frac{th}{}R \quad \frac{i}{}*R$$

$$_{oc}$$

$$_{th}$$

R_{th} is the total thermal resistance to heat flow from the centre conductor to the ambient air and is calculated by summing the insulation and jacket thermal resistance. The metallic components of the cable construction are considered to be isotherms and therefore disregarded.

where

$$R_{th} = R_i + R_j$$

$$R_i = 0{,}005\,22 * \rho_i * \ln \frac{C}{d}$$

$$R_j = 0{,}005\,22 * \ln \frac{D}{D_i}$$

The variables used in the previous equations are defined as follows:

I = current carrying capacity (Amperes);

tc = conductor operating temperature (°C);

ta = ambient temperature (°C) ; ts = cable surface temperature;

Ric = inner conductor resistance (Ohm/m);

Roc = outer conductor resistance (Ohm/m);

Reoc = increase in Ric due to outer conductor (Ohm/m);

Rth = total thermal resistance of circuit (°C/Watt/m);

Ri = thermal resistance of dielectric (°C/Watt/m);

Rj = thermal resistance of jacket (°C/Watt/m);

ε = surface emissivity (jacketed=0,95, bare=0,35);

ρ i = thermal resistivity of the dielectric material
= 3 900 °C/watt/m for both foam and disc & air dielectrics;

ρ j = thermal resistivity of the jacket material
= 1 200 °C/watt/m for polyethylene (PE) jackets
= 1 000 °C/watt/m for polyvinylchloride (PVC) jackets;

n = number of cables;

d = centre conductor diameter (mm);

C = insulation diameter (mm);

Ds = outer conductor diameter (mm);

D = jacket diameter (mm).

Maximum permissible input power is given by

$$P_{max} = Z_{c\,mean} * I^2$$

where Zc is the characteristic impedance of the cable.

6.6.2 Balanced cables

The current rating of balanced cables obviously may be computed using the same approach than the one used for coaxial cables depending upon the insulation materials, design, diameters, and environmental conditions. However, in practice the following rules of thumb may be used.

When the conductor temperature rise shall be less than 10 °C the current density shall not exceed 3 A/mm².

When the conductor temperature rise shall be less than 5 °C the current density shall not exceed 0,9 A/mm².

7 Standard values of characteristic impedance and outer diameter of dielectric for coaxial cables

7.1 Impedance of coaxial cables

All impedances specified in this clause are defined at a frequency of 200 MHz and at the reference temperature of 20 °C.

Standard values of nominal characteristic impedance are

– 50 Ω,

– 75 Ω,

– 93 Ω.

7.2 Nominal diameters over dielectric of coaxial cables

Nominal diameters D_2 over dielectric and the tolerances thereon shall be in accordance with the following table:

Table 13 – Nominal diameters over dielectric

Dielectric	Impedance Ω		Diameter over dielectric mm	
	Rated value	Tolerance ±	Rated value	Tolerance ±
			1,50	0,10
			2,95	0,13
			3,70	0,15
		2,0		
			4,80	0,20
			6,40	0,20
	50			
			7,25	0,25
		1,0 [a]	7,25	0,15
			11,50	0,30
		2,0	17,30	0,40
Solid				
			23,70	0,30
polyethylene				
			1,50	0,10
		3,0	2,95	0,13
			3,70	0,13
		1,5 [a]	3,70	0,10
	75		4,80	0,20
		3,0	7,25	0,25
		1,5 [a]	7,25	0,15
			17,30	0,40
		3,0	23,70	0,30
			1,50	0,10
		5,0	2,30	0,10
			2,95	0,13
	50		4,80	0,20
Cellular			5,85	0,20
		4,0		
polyethylene				
			6,25	0,20
			7,25	0,25
			3,70	0,15
	75	5,0	4,80	0,20
			7,25	0,25
	50	2,5	7,25	0,25
Semi-air-spaced				
			2,50	0,15
polyethylene	93	5,5		
			3,70	0,13
			0,87	0,07
		3,5	1,50	0,10
	50	2,5	2,95	0,13
			7,25	0,15
Polytetrafluoro-ethylene		2,0	11,50	0,30
		5,0	1,50	0,10
	75	3,0		
			3,70	0,13
			7,25	0,25

	93	5,5	2,60	0,13
	50	2,5	2,40	0,08
Cellular fluorinated ethylene-propylene			3,40	0,13
	75	3,5	4,30	0,08
			7,25	0,25
	93	5,5	3,70	0,13

[a] Close tolerance cables.

8 Coaxial cable construction details

8.1 General

The starting point is to determine

a) the nominal characteristic impedance, Z_0 (according to 7.1),

b) the outer diameter of dielectric, D_2 (according to 7.2),

c) the permittivity of dielectric, ε_2 (Table 4).

Calculate the effective diameter of outer conductor, D_{3e}.

Table 14 – Special design features

Outer conductor	Diameter D_{3e}
Tubular	$D_{3e} = D_2$
Braided	$D_{3e} > D_2$ (see 17)

8.2 Inner conductor

The electrical effective diameter D_{1e} of the inner conductor follows from

$$D_{1e} = D_{3e} \exp\left(-z_0 \sqrt{\varepsilon_2} / 60\right)$$

Table 15 – Special design features

Solid inner conductor	Diameter D_1 as calculated
Stranded inner conductor	Diameter $D_1 > D_{1e}$ (see 6.3)

8.3 Stranded inner conductor

The diameter D_1 is to be calculated from the effective diameter D_{1e}:

$$D_1 = D_{1e} / k_{1z}$$

The wire diameter d_1 is to be calculated from D_1:

$$d_1 = D_1 / k_{1d}$$

k_{1d} and k_{1z} according to Table 9.

8.4 Braided outer conductor

Table 16 – Braids

The effective diameter D_{3e}

outer diameter D_3

mean diameter D_{3m}

are to be calculated from the outer diameter D_2 and the diameter of the braid wires d_3:

$D_{3e} = D_2 + 1{,}5\ d_3$

$D_3 = D_2 + 4{,}5\ d_3$

$D_{3m} = D_2 + 2{,}25\ d_3$ d_3 according to Table 11

The filling factor of the braid is:

$$q_3 = \frac{N_3\, n_3\, d_3\, k_{3r}}{2\pi D_{3m}}$$

d_3 and D_{3m} as above

k_{3r} according to Table 10

The coverage and the braid angle of the outer conductor are given by:

$B_3 = 2q_3 - q_3^2$ $\beta_3 = \arctan \pi D_{3m}/L_3$

8.5 Medium between outer conductor and screen

Table 17 – Inner sheath

The outer diameter of the interposed medium is:

$$D_5 = D_3 + 2\ s_5$$

8.6 Braided screen

Table 18 – Braided screen

The outer diameter D_6 and the mean diameter D_{6m} are to be calculated from the outer diameter of the interposed medium D_5 and the diameter of the braid wires, d_6:

$D_6 = D_5 + 4{,}5\ d_6$

$D_{6m} = D_5 + 2{,}25\ d_6$

d_6 according to Table 11

The filling factor of the braid is:

$$q_6 = \frac{N_6\, n_6\, d_6\, k_{6r}}{2\pi D_{6m}}$$

d_6 and D_{6m} as above

k_{6r} according to Table 10

The coverage and the braid angle of the screen are given by:

$B_6 = 2q_6 - q_6^2$ $\beta_6 = \arctan \pi D_{6m}/L_6$

8.7 Sheath

Table 19 – Sheath

Material	Outer diameter of screen D_6 [a b]	Nominal thickness s_4	Minimum thickness s_4 min.
FEP	< 2,5	0,25 mm	0,15 mm
PTFE	2,5-5,9	0,38 mm	0,25 mm
	6,0-9,0		0,30 mm
PE	< 2,5	0,07 D_6 1) + 0,3 mm	0,9 s_4 – 0,1 mm
PVC	≥ 2,5	0,07 D_6 1) + 0,5 mm	

a Cables without screen: to be replaced by outer diameter of outer conductor D_3.

b For cables with outer diameter outside the given range the nominal and minimum thickness are not defined here.

8.8 Attenuation

The total attenuation per unit length is to be calculated from

$$\alpha = \alpha_1 + \alpha_2 + \alpha_3$$

where α_1, α_2 and α_3 are the attenuation components due to the inner conductor, dielectric and outer conductor.

The attenuation is related to a cable temperature of 20 °C. For temperatures $T \neq 20$ °C, the attenuation shall be calculated by

$$\alpha_T = (\alpha_1 + \alpha_3)\sqrt{1 + 0{,}003\,93\,(T - 20\ °C)} + \alpha_2$$

NOTE α_2 may be temperature dependent for some dielectric materials.

Formulae for calculation of α_1, α_2 and α_3 are given in the following table. These formulae are applicable for frequencies ≥ 10 MHz. Formulae for lower frequencies are under consideration.

Table 20 – Attenuation formula

$\alpha_1 = \frac{4{,}58\, k_{1c}\, k_{1a} \cdot \sqrt{\varepsilon_2\, f}}{D_{1e} \ln(D_{3e}/D_{1e})}\,\chi_1$	χ_1 and χ_3, k_{1c} and k_{3c} according to Tables 5 and 6
$\alpha_2 = 9{,}1 \sqrt{\varepsilon_2} \cdot \tan\delta_2\, f$	k_{1a} and k_{3a} according to Table 12
	ε_2 and tan δ_2 according to Table 4
$\alpha_3 = \frac{4{,}58\, k_{3c}\, k_{3a} \cdot \sqrt{\varepsilon_2\, f}}{D_{3e} \ln(D_{3e}/D_{1e})}\,\chi_3$	D_{1e} and D_{3e} according to 15 and to Table 14 or to 16

8.9 Nominal characteristic impedance Z_0 and capacitance C_2 per unit length

$$Z_o = \frac{60}{\sqrt{\varepsilon_2}} \ln \frac{D_{3e}}{D_{1e}}$$

$$C_2 = \frac{\sqrt{\varepsilon_2}}{3 Z_o} \cdot 10^4 \quad \text{(pF/m)}$$

ε_2 according to Table 4;

D_{3e} according to Table 14 or to 17;

D_{1e} according to 15.

9 Standard values of characteristic impedance and outer diameter of dielectric for symmetrical cables

9.1 Impedance of symmetrical cables

All impedances specified in this clause are defined at a frequency of 100 MHz and at the reference temperature of 20 °C.

Standard values of nominal characteristic impedance are

- 100 Ω,
- 120 Ω,
- 150 Ω.

10 Symmetrical cable construction details

The characteristic impedance at the asymptote can be derived from the following equation:

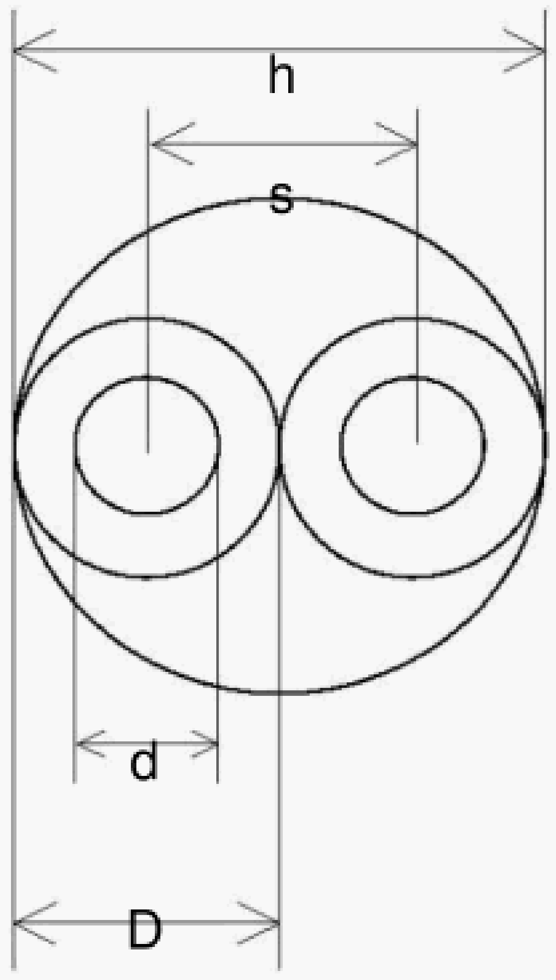
$$Z_\infty = \frac{\sqrt{\varepsilon}}{C \times c} \quad \text{in Ohms}$$

where

ε is the relative permitivity of the insulation material,

C is the capacitance of the cable (F/m),

c is the speed of light in vacuum (3 10^8 m/s).



In a first approach the capacitance may be computed with an acceptable accuracy using the following equation.

$$C = \frac{12.1 \times \varepsilon}{\log\left(\frac{2 \times s}{d} \times \frac{h^2 - s^2}{h^2 + s^2}\right)} \quad \text{in pF/m}$$

where

ε is the relative permitivity of the insulation material,

C is the capacitance of the cable (pF/m),

s is the distance between the centre of the conductors (mm),

d is the diameter of the wires (mm),

D is the diameter of the insulated wire,
h is the overall diameter (mm).

10.1 Attenuation

The attenuation of symmetrical cables may be written as: $\alpha = A + B\sqrt{f} + Cf$ or

ρ – R √ √ √

α = + + + LC + tan

2L ρ ω ρ ω δ ω δ

√ √ tan

2Z 2Z 4Z 2

where

– R and L are computed from the cable dimensions taking into account the skin effect and the proximity effects and Z is the characteristic impedance at the asymptote,

$R_s = \sqrt{\ } \; _0 r \; R$

– ρ = * 2μσ / 4 ω

R_s is the square root of the frequency dependant component (Ohm/m),
σ is the specific conductivity of the wire material (S/m),
μ is the permeability of the wire material,
R_0 is the DC resistance of a round wire with a radius r.

However, it is possible to use a fitting function to harmonise the predicted and measured result using:

$$\alpha' = \frac{A' + B'\sqrt{f} + C'f}{\ }$$

α ' = ' f A + B f + Cf

11 Common characteristics

11.1 Weight calculation

The approximate total weight of the cable is to be calculated from $m = \Sigma m_x$.

For the calculation of the individual weights, formulae are given in the following table:

Table 21 – Weight

	—	
	—	
	—	
	—	
	—	
Solid inner conductor	πD 2	

	$m_1 = \frac{\pi}{4} d_1^2 \cdot \gamma_1$	γ_1 according to Table 5 k_{1r} according to Table 9
Stranded inner conductor	$m_1 = \frac{\pi}{4} d_1^2 \cdot N_1 k_{1r} \gamma_1$	γ_2 according to Table 4
Insulation	$m_2 = \frac{\pi}{4} (D_2^2 - D_1^2) \gamma_2$	D_1 according to 16
Tubular outer conductor	$m_3 = \pi (D_2 + s_3) s_3 \gamma_3$	γ_3 according to Table 5
Braided outer conductor	$m_3 = \frac{\pi}{4} d_3^2 \cdot N_3 n_3 k_{3r} \gamma_3$	k_{3r} according to Table 10
Interposed medium between outer conductor and screen	$m_5 = \pi (D_3 + s_5) s_5 \gamma_5$	γ_5 dependent on the material used D_3 according to Table 17
Braided screen	$m_6 = \frac{\pi}{4} d_6^2 \cdot N_6 n_6 k_{6r} \gamma_6$	γ_6 according to Table 5 k_{6r} according to Table 10
Sheath	$m_4 = \pi (D_6 + s_4) s_4 \gamma_4$ [1]	γ_4 according to Table 4

1) For cables without screen, D6 is to be replaced by D3.

12 Calculation of electrical properties

12.1 DC resistance of conductors and screen, per unit length

The values are to be calculated from the formulae in the following table:

Table 22 – DC Resistance

Solid inner conductor	$R_1 = \frac{4\chi_1}{\pi D_1^2}$	χ_1, χ_3, χ_6 according to Table 5 k_{1r} according to Table 9 k_{3r} and k_{6r} according to Table 10 d_3 and d_6 according to Table 11
Stranded inner conductor	$R_1 = \frac{4 k_{1r} \chi_1}{N_1 \pi d_1^2}$	
Tubular outer conductor	$R_3 = \frac{\chi_3}{\pi (D_2 + s_3) s_3}$	
Braided outer conductor	$R_3 = \frac{4 k_{3r} \chi_3}{N_3 n_3 \pi d_3^2}$	
Braided screen	$R_6 = \frac{4 k_{6r} \chi_6}{N_6 n_6 \pi d_6^2}$	

12.2 Permissible voltages

12.2.1 Test voltage, dielectric, U_t

The maximum value of voltage gradient is to be found at the surface of the inner conductor. It is limited by the maximum permissible voltage gradient E_2 of the dielectric. Hence the test voltage U_{tc} (r.m.s. value) is to be calculated from the formula:

$$U_{tc} = \frac{E_2 \cdot D_1 \cdot k_2}{2 \cdot \sqrt{2}} \ln \frac{D_{3e}}{D_{1e}}$$

- E_2 according to Table 4;
- k_2 according to Table 9;
- D_1 according to 16;
- D_{1e} according to 15;
- D_{3e} according to Table 14 or to 17.

The value of U_{tc} shall then be rounded to the nearest 0,2 kV for values below 5 kV and to the nearest 0,5 kV for values of 5 kV and more. The rounded test voltage is designated U_t. The rounded test voltage shall be applied for 2 min at a frequency of 40 Hz to 60 Hz.

For symmetrical cables:

- Voltage between conductors / conductors and the screen:

D1 is the wire diameter,
D3 is twice the insulated wire diameter minus the wire diameter.

K_2 is 1.

12.2.2 Discharge test voltage, dielectric, U_d

The discharge test voltage U_d (r.m.s. value) is given by the formula $U_d = 0{,}5\ U_t$ except in the case for polytetrafluoroethylene where the following applies:

$U_d = 0{,}4\ U_t$ with a minimum of 1 kV

12.2.3 Test voltage, sheath

For PVC sheaths:

Table 23 – Test voltages

Nominal thickness of the sheath (s_4) mm	**Test voltage** kV r.m.s.	
	Immersion test	**Spark test**
Up to and including 0,5	No test	No test
Over 0,5 up to and including 0,8	2	3
Over 0,8 up to and including 1,0	3	5
Over 1,0	5	8

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