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Access, Terminals, Transmission and Multiplexing (ATTM); Deployment of Indoor Fibre Distribution Network Hybrid Cabling System

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

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1 Scope

The present document describes the structure of the Indoor Fibre Distribution Network (IFDN) Hybrid Cabling System, main functional elements and their characteristics, deployment details and acceptance items.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long-term validity.

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] IEC 60228: "Performance characteristics and calibration methods for digital data acquisition systems and relevant software".

[i.2] IEC 60332-1-2: "Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1 kW pre-mixed flame".

[i.3] IEC 60512-1-1: "Connectors for electronic equipment - Tests and measurements - Part 1-1: General examination - Test 1a: Visual examination".

[i.4] IEC 60512-1-2: "Connectors for electronic equipment - Tests and measurements - Part 1-2: General examination - Test 1b: Examination of dimension and mass".

[i.5] IEC 60512-2-1: "Connectors for electronic equipment - Tests and measurements - Part 2-1: Electrical continuity and contact resistance tests - Test 2a: Contact resistance - Millivolt level method".

[i.6] IEC 60512-2-5: "Connectors for electronic equipment - Tests and measurements - Part 2-5: Electrical continuity and contact resistance tests - Test 2e: Contact disturbance".

[i.7] IEC 60512-3-1: "Connectors for electronic equipment - Tests and measurements - Part 3-1: Insulation tests - Test 3a: Insulation resistance ".

[i.8] IEC 60512-4-1: "Connectors for electronic equipment - Tests and measurements - Part 4-1: Voltage stress tests - Test 4a: Voltage proof".

[i.9] IEC 60512-6-3: "Connectors for electronic equipment - Tests and measurements - Part 6-3: Dynamic stress tests - Test 6c: Shock".

[i.10] IEC 60512-6-4: "Connectors for electronic equipment - Tests and measurements - Part 6-4: Dynamic stress tests - Test 6d: Vibration (sinusoidal)".

[i.11] IEC 60512-11-4: "Connectors for electronic equipment - Tests and measurements - Part 11-4: Climatic tests - Test 11d: Rapid change of temperature".

[i.12] IEC 60512-11-9: "Connectors for electronic equipment - Tests and measurements - Part 11-9: Climatic tests - Test 11i: Dry heat".

[i.13] IEC 60512-11-10: "Connectors for electronic equipment - Tests and measurements - Part 11-10: Climatic tests - Test 11j: Cold".

[i.14] IEC 60512-11-12: "Connectors for electronic equipment - Tests and measurements - Part 11-12: Climatic tests - Test 11m: Damp heat, cyclic".

[i.15] IEC 60512-13-2: "Connectors for electronic equipment - Tests and measurements - Part 13-2: Mechanical operation tests - Test 13b: Insertion and withdrawal forces".

[i.16] IEC 60754-2: "Test on gases evolved during combustion of materials from cables - Part 2: Determination of acidity (by pH measurement) and conductivity".

[i.17] IEC 60793-1-40: "Optical fibres - Part 1-40: Attenuation measurement methods".

[i.18] IEC 60794-1-101: "Optical fibre cables - Part 1-101: Generic specification - Basic optical cable test procedures - Mechanical tests methods - Tensile, method E1".

[i.19] IEC 60794-1-104: "Optical fibre cables - Part 1-104: Generic specification - Basic optical cable test procedures - Mechanical tests methods - Impact, method E4".

[i.20] IEC 60794-1-111: "Optical fibre cables - Part 1-111: Generic specification - Basic optical cable test procedures - Mechanical tests methods - Bend, method E11".

[i.21] IEC 60794-1-21: "Optical fibre cables - Part 1-21: Generic specification - Basic optical cable test procedures - Mechanical tests methods".

[i.22] IEC 60794-1-201: "Optical fibre cables - Part 1-201: Generic specification - Basic optical cable test procedures - Environmental test methods - Temperature cycling, method F1".

[i.23] IEC 60874-14-5: "Connectors for optical fibres and cables - Part 14-5: Detail specification for fibre optic connector type SC-PC untuned terminated to single-mode fibre type B1".

[i.24] IEC 61034-2: "Measurement of smoke density of cables burning under defined conditions - Part 2: Test procedure and requirements".

[i.25] IEC 61300-2-1: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-1: Tests - Vibration (sinusoidal)".

[i.26] IEC 61300-2-2: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-2: Tests - Mating durability".

[i.27] IEC 61300-2-4: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-4: Tests - Fibre or cable retention".

[i.28] IEC 61300-2-5: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-5: Tests - Torsion".

[i.29] IEC 61300-2-6: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-6: Tests - Tensile strength of coupling mechanism".

[i.30] IEC 61300-2-9: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-9: Tests - Shock".

[i.31] IEC 61300-2-17: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-17: Tests - Cold".

[i.32] IEC 61300-2-18: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-18: Tests - Dry heat".

[i.33] IEC 61300-2-19: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-19: Tests - Damp heat (steady state)".

[i.34] IEC 61300-2-22: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-22: Tests - Change of temperature".

[i.35] IEC 61300-2-26: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-26: Tests - Salt mist".

[i.36] IEC 61300-2-44: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-44: Tests - Flexing of the strain relief of fibre optic devices".

[i.37] IEC 61300-3-3: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-3: Examinations and measurements - Active monitoring of changes in attenuation and return loss".

[i.38] IEC 61300-3-4: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-4: Examinations and measurements - Attenuation".

[i.39] IEC 61300-3-6: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-6: Examinations and measurements - Return loss".

[i.40] IEC 61300-3-28: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-28: Examinations and measurements - Transient loss".

[i.41] IEC 61300-3-34: "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-34: Examinations and measurements - Attenuation of random mated connectors".

[i.42] IEC 61753-1: "Fibre optic interconnecting devices and passive components - Performance standard - Part 1: General and guidance".

[i.43] IEC 61754-4:2022: "Fibre optic interconnecting devices and passive components - Fibre optic connector interfaces - Part 4: Type SC connector family".

[i.44] IEC 62368-1:2023 RLV: "Audio/video, information and communication technology equipment - Part 1: Safety requirements".

[i.45] IEC 63294-2021: "Test methods for electric cables with rated voltages up to and including 450/750 V".

[i.48] IEEE 802.3af™: "IEEE Standard for Information Technology -Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications - Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI)".

[i.49] IEEE 802.3at™: "IEEE Standard for Information technology - Local and metropolitan area networks - Specific requirements - Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment 3: Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements".

[i.50] IEEE 802.3bt™: "IEEE Standard for Ethernet Amendment 2: Physical Layer and Management Parameters for Power over Ethernet over 4 pairs".

[i.51] Recommendation ITU-T G.9940 (ex G.fin-SA): "High speed fibre-based in-premises transceivers - system architecture".

[i.52] UL 94: "Test for Flammability of Plastic Materials for Parts in Devices and Appliances".

[i.53] EN 55032: "Electromagnetic compatibility of multimedia equipment - Emission Requirements", (produced by CENELEC).

[i.54] EN 55035: "Electromagnetic Compatibility of Multimedia equipment - Immunity Requirements", (produced by CENELEC).

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in Recommendation ITU-T G.9940 [i.51] (ex G.fin-SA) and the following apply:

hybrid cabling system: system that supports the connection of information technology equipment and transmission of optical signal and power supply and usually consist of active distribution units (optical & electrical splitter), optical & electrical hybrid cable, and optical & electrical hybrid connector

Indoor Fibre Distribution Network (IFDN): point-to-multipoint optical fibre infrastructure for fibre-based in-premises network

NOTE: An IFDN can be entirely passive, constructed by one or multiple interconnected optical splitter and contains other passive optical components, like combiners, filters, and possibly other passive optical components. The IFDN can also provide remote power feed functionality to Sub FTTR unit (SFU) by using optical and electrical hybrid cables.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ADU	Active Distribution Unit
CE	Conducted Emission
CS	Injected currents
EMC	ElectroMagnetic Compatibility
ESD	Electro-Static Discharge
FDT	Fibre Distribution Terminal
IFDN	Indoor Fibre Distribution Network
LSZH	Low Smoke Zero Halogen material
MFU	Main FTTR Unit
PoHC	Power over Hybrid Cable
RE	Radiated Emission
RS	RF electromagnetic field
SFU	Sub FTTR Unit

4 Structure of IFDN Hybrid Cabling System

4.1 General

An Indoor Fibre Distribution Network (IFDN) is mainly composed of optical splitter or optical & electrical splitter, optical cable or optical &electrical hybrid cable, fibre connector or optical & electrical hybrid connector. The position of the IFDN cabling system is shown in Figure 4.1. Traditional optical fibre networking uses optical cables and corresponding power supply facilities for networking. A hybrid cabling system can effectively obtain local power, which can maximize utilization of existing infrastructure to optimize the cost of deployment and maintenance. The present document focuses on the IFDN hybrid cabling system.

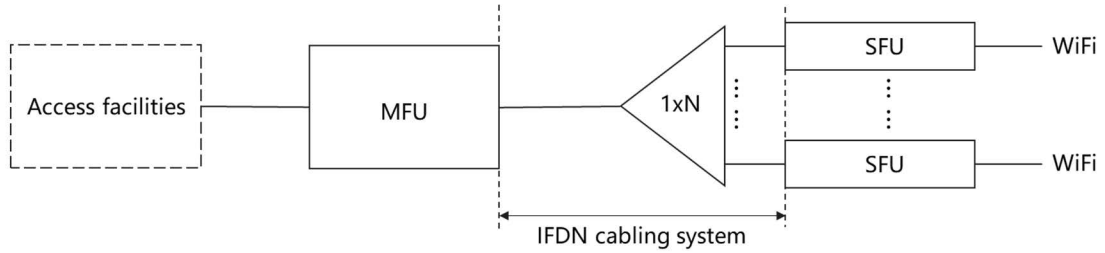


Figure 4.1: Position of IFDN cabling system

Based on the user density, the IFDN hybrid cabling system can be divided into four typical network structures with different splitting ratio and splitter layout: one-level even splitting structure, one-level uneven splitting structure, multi-level uneven splitting cascade structure and multi-level even splitting cascade structure. The IFDN cabling structure is advisable to be determined based on the use scenarios.

In low-density user scenarios, one-level even ratio or uneven ratio networking structures as showed in Figure 4.2 are usually deployed. The even splitting ratio can be 1:4, 1:5, 1:8 or 1:16, and the uneven splitting ratio can be 1:9.

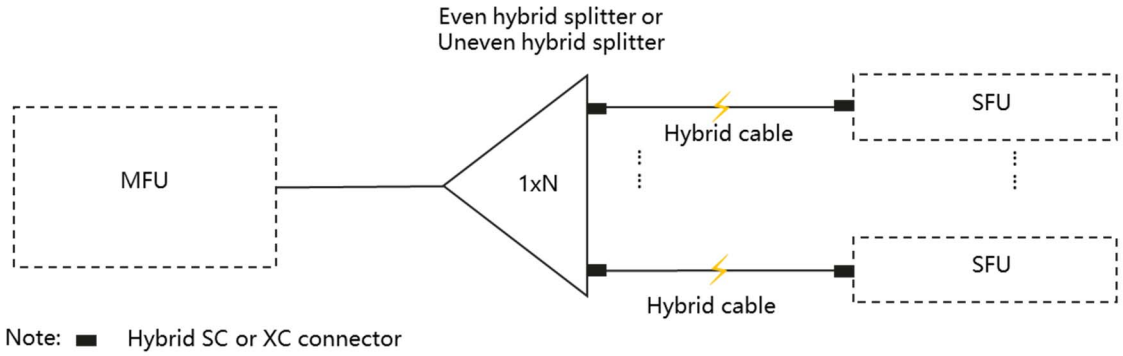


Figure 4.2: Structure of one-level splitting IFDN hybrid cabling system

In medium-density user scenarios, the two-level even ratio optical cascade network can be used to increase the number of Sub FTTR Units (SFUs). The uneven splitter ratio can be 1:5, as showed in Figure 4.3.

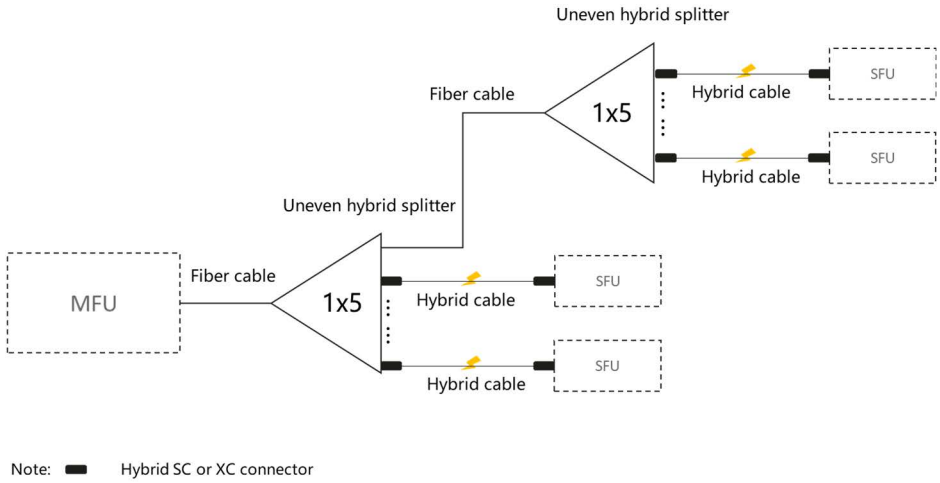


Figure 4.3: Structure of 1:5 uneven ratio cascading IFDN hybrid cabling system

In high-density user scenarios both the multi-level uneven ratio and even ratio optical cascade network can be used to increase the number of SFU. For uneven ratio optical cascade network, the uneven ratio can be 1:9 as showed in Figure 4.4. For even ratio optical cascade network, as showed in Figure 4.5, the first level even ratio can be 1:4, and the second level even ratio can be 1:16.

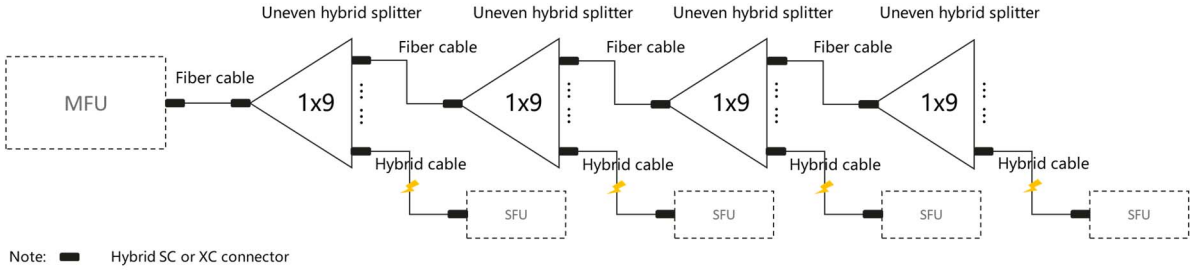


Figure 4.4: Structure of 1:9 uneven ratio cascading IFDN hybrid cabling system

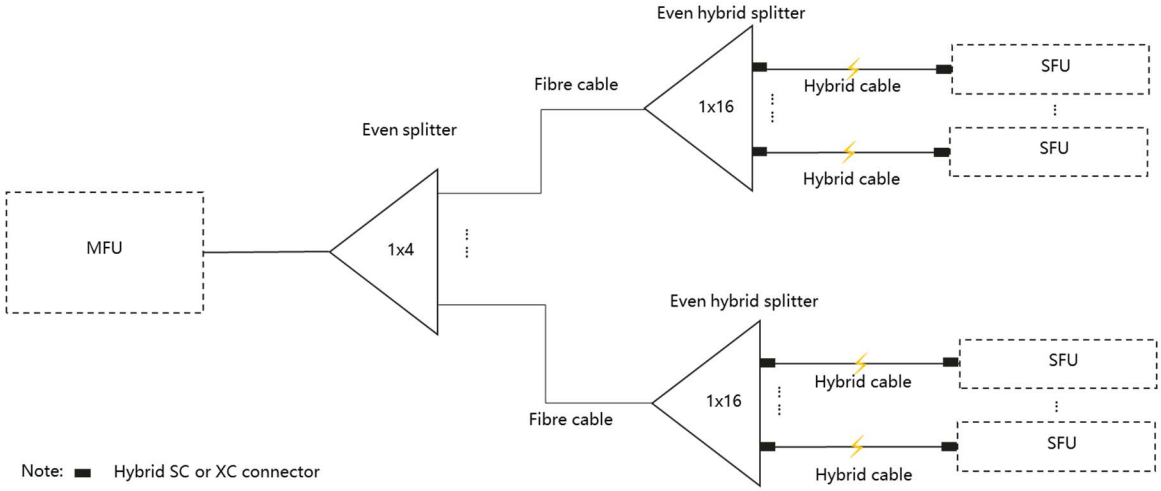


Figure 4.5: Structure of even ratio cascading IFDN hybrid cabling system

4.2 Power over Hybrid Cable (PoHC)

Power over Hybrid Cable (PoHC) is a method of providing both power and data to a device by hybrid cable.

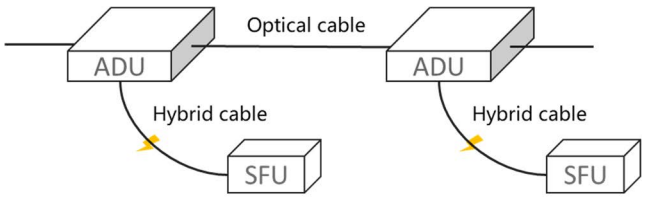


Figure 4.6: PoHC system

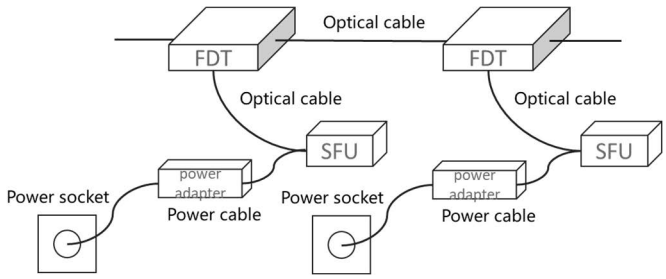


Figure 4.7: Common power and optical cabling system

To solve the problem of compatibility between power supply and power receiving devices from different manufacturers and provide safety of use, ADU and SFU should support IEEE 802.3af [i.48], IEEE 802.3at [i.49] or IEEE 802.3bt [i.50] standard.

4.3 Function elements

In the IFDN hybrid cabling system, the key function units mainly include active distribution units (hybrid splitter), hybrid cable and hybrid connector.

1) Active Distribution Unit:

   The Active Distribution Unit (ADU), which is an active optical device containing splitter, is the key part to connect the MFU and the SFU and to provides optical signals and power input for the SFU. It can be installed in an indoor information box or on a wall. The functions include:

   - Photoelectric composite interface.
   - Internal integrated optical splitter.
   - Each port with electrical security protocol.

2) Hybrid cable:

   It is a composite cable that integrates optical fibre and power transmission copper wire. It can provide data transmission and remote power supply for terminal equipment, and the data transmission rate is no less than 1 Gbit/s.

3) Hybrid connector:

   It is a double-ended prefabricated photoelectric composite connector. The typical products include type XC and type SC hybrid connector. Type XC hybrid connector has small outer diameter, light weight and small occupied space. Type SC hybrid connector has good compatibility with the interface same as type SC optical connector.

5 Hybrid cable

5.1 Structure

The hybrid cable is typically composed of optical fibre elements and current carrying elements, strength member (possible), filler (possible), yarn (possible) tape (possible), ripcord (possible), sheath, etc. The hybrid cable should meet the requirements of the application and operating environment.

Typical FTTR (IFDN) hybrid cables include the round-type, bow-type, and flat-type. Sectional views of typical structures are shown in Figures 5.1 to 5.3.

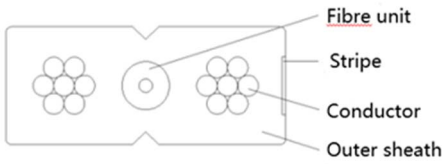


Figure 5.1: Bow-type Hybrid cable

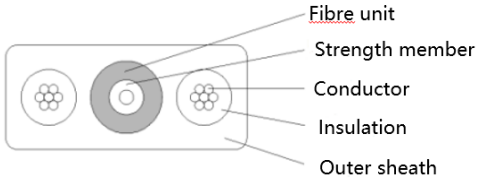


Figure 5.2: Flat-type Hybrid cable

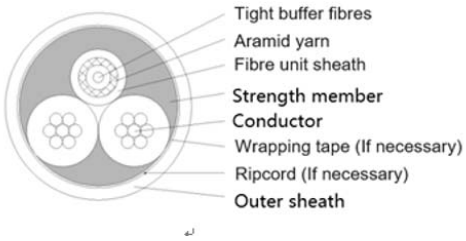


Figure 5.3: Round-type Hybrid cable

5.2 Optical fibre elements

The optical fibre elements can be composed of one or more optical fibres, tight or semi-tight buffered fibres, fibre ribbons, buffer tubes, or other optical core structures, or independent optical fibre cables (such as loose tube cable).

The optical fibre elements should be in accordance with the following:

a) For ease of identification, all the optical fibre and optical fibre elements should be identified by colour coding, ring marking, printing or any other ways as agreed between the customer and the supplier. If the primary coated fibres are coloured for identification, the coloured coating needs to be readily identifiable throughout the lifetime of the cable.

b) The material of the optical elements' sheath or loose tube could be polyethylene, polypropylene, Polybutylene Terephthalate (PBT), Low Smoke Zero Halogen (LSZH) material, polyvinyl chloride or other materials suitable to the application.

5.3 Current carrying elements

The design of the conductor cross-sections needs to be in according with the rated voltage, transmission distance and consumed power of the powered device.

Current carrying elements could be copper or other conductive material.

The conductor needs to be continuous without joints through the length of the hybrid cable.

5.4 Strength member

Strength members should be made of aramid yarn or other material, and be placed in a suitable position according to the structure of the hybrid cable.

5.5 Outer sheath

Polyethylene, polypropylene, PVC, polyurethane, flame retardant low smoke polyolefin and other suitable materials can be used.

5.3 Optical transmission performance

Optical transmission performance for cabled optical fibre elements need to conform to Table 5.1.

Table 5.1: Optical transmission performance for cabled optical fibre elements

Parameter	Test procedure	Requirements/Remarks
Attenuation coefficient at 1 550 nm	IEC 60793-1-40 [i.17]	⩽0,30 dB/km for B-652.D ⩽0,30 dB/km for B-657
Attenuation coefficient at 1 300 nm	IEC 60793-1-40 [i.17]	⩽1,5 dB/km for A1-OM1 to A1-OM5

5.4 Electrical performance

Electrical performance for current carrying elements need to conform to Table 5.2.

Table 5.2: Electrical performance for current carrying elements

No	Test	Severity	Requirement
1	Conductor DC resistance IEC 60228 [i.1], Annex A	Test equipment: A current source in conjunction with a voltmeter Sample length under test: Not less than 1 m	The measured value needs to be recalculated to the standard temperature of 20 ºC and needs to conform to relevant specification
2	Dielectric withstand voltage IEC 63294-2021 [i.45], clause 5.3	1,5 KV (AC), 1 min	No breakdown of the insulation
3	Insulation resistance IEC 63294-2021 [i.45], clause 5.4	Test in ambient temperature 20 °C and higher temperature 70 °C or according to relevant detail specifications. 80 V DC to 500 V DC	The measured value needs to conform to relevant specification

5.5 Mechanical performance

The mechanical tests will affect all the elements of the cable to some degree. The cable should be tested as a whole, rather than discrete elements.

Tests on single mode fibre cables should be carried out at 1 550 nm. Multimode fibre cables should be tested at 1 300 nm. Measurements at other wavelengths or wavelength range may be agreed upon between the customer and the supplier.

Mechanical performance tests should conform to Table 5.3.

Table 5.3: Mechanical performance tests

No.	Test	Severity	Criteria
1	Tensile performance IEC 60794-1-101 [i.18]	Length of the cable under tension: $\geqslant$ 50 m Diameter of test pulleys: $\geqslant$ 20 D (D is diameter of finished cable). Long-term tensile load (T_L): 80 N for cables with strength member (e.g. Aramid yarn), 60 N for cables without strength member Short-term tensile load (T_M): 150 N for cables with strength member (e.g. Aramid yarn), 120 N for cables without strength member Duration: 10 min for long term tensile force,1 min for short term tensile force Rate of tension increase: 100 mm/min	O (see note 3), E (see note 4), V The axial fibre strain should be less than 60 % of the fibre proof strain while the cable is under short-term tensile load While the cable is under the long-term tensile load, the axial fibre strain should be less than 20 % of fibre proof test, for fibre proof tested to $\leqslant$ 1 % strain (e.g. 0,69 GPa, 0,2 % absolute strain) See note 1.
2	Crush IEC 60794-1-21 [i.21], Method E3A	Not less than 3 pieces of the sample, each separated 500 mm The load needs to be applied on the wider side of the cable Long-term load: 1,1 KN Short-term load: 2,2 KN Duration: 10 min for long term load, 1 min for short term load	O (see note 5), E, V
3	Impact IEC 60794-1-104 [i.19]	Impact energy: 1 J or agreed between customer and supplier 3 impact points, impact one time per point, every point spaced not less than 500 mm apart Radius of striking surface:12,5 mm	O, E, V (see note 6)

No.	Test	Severity	Criteria
4	Repeated bending IEC 60794-1-21 [i.21], Method E6	Mass of the weight tensile load: Adequate to assure specimen uniform contact with the mandrel Bending radius: 20 D (D is diameter of round cable or the short axis length of bow-type and flat-type cable) Number of cycles: 25	O, E, V
5	Torsion IEC 60794-1-21 [i.21], Method E7	Tension load: Adequate to assure the specimen to be straight Length under test: 1 m Rotating angle (see note 6) : ±180° Number of cycles: 10	O, E, V
6	Bend IEC 60794-1-111:2023 [i.20]	Diameter of mandrel: 20 D (D is diameter of finished cable) Number of cycles: 10 Number of turns: 6 Test temperature: Ambient (unless specifically requested otherwise)	O, E, V

NOTE 1: For fibres proof tested at levels above 1 % strain, the safe long-term load will not scale linearly with proof strain, so a lower percentage of the proof stain is applicable.

NOTE 2:

- 'O' means no change in attenuation as defined in IEC 60794-1-21 [i.21] after the test.
- 'E' means dielectric withstand voltage needs to conform to Table 5.2 after the test.
- 'V' means visual examination, no damage to the sheath or to the cable elements.

NOTE 3: The change in attenuation during the test needs to be no more than 0,1 dB at 1 550 nm.

NOTE 4: The maximum increase in attenuation during the test with a long-term force needs to be specified in the product specification.

NOTE 5: The imprint of the striking surface on the sheath is not considered a mechanical damage.

NOTE 6: If the specified twist angle applied to the cable results in a high torsional torque that is not suitable for the cable type, then the rotating angle should be lowered as specified by the manufacturer.

5.6 Environmental performance

Environmental performance tests should conform to Table 5.4.

Table 5.4: Environmental performance tests

No.	Test	Test Method	Severity	Criteria
1	Temperature cycling	IEC 60794-1-201 [i.22]	Length under test: finished cable length, not less than 1 000 m - 10 °C~60°C Duration at extreme temperatures: 8 h Rate of temperature changing: 1°C/min Number of cycles: 2	Attenuation measurements should be taken at 1 550 nm for single-mode fibre and 1 300 nm for multimode fibre after the test. During the test, change in attenuation should be no more than 0,4 dB/km at 1 550 nm. The dielectric withstand voltage should comply with Table 5.2. Under visual examination without magnification no damage to the sheath or to the cable elements.

No.	Test	Test Method	Severity	Criteria
2	Flame test	Flame propagation IEC 60332-1-2 [i.2] or other methods agreed between customer and supplier		Pass the IEC 60332-1-2 [i.2] single cable vertical flame propagation test. The distance between the lower edge of the top support and the onset of charring is greater than 50 mm. The distance from the lower edge of the top support to the lower onset of charring is less than 540 mm.
		Emission of smoke (for cables with LSZH material) IEC 61034-2 [i.24]		Transmittance ⩾ 60 %
		Emission of corrosive gases (for cables with LSZH material) IEC 60754-2 [i.16]		Acidity PH ⩾ 4,3, Conductivity ⩽ 10 μS/mm

6 Hybrid Connector

6.1 Structure

A Hybrid connector in the IFDN Hybrid Cabling System is a miniaturized plug-in connector that consists of a single-core plug and an adapter, with optical and electrical connection characteristics. It is used to transmit signals and remotely supply power to low-power terminals such as WLAN devices and cameras.

At present, single mode hybrid connectors are mainly used in IFDN Hybrid Cabling System, and the most widely used hybrid connectors include type XC hybrid connector and type SC hybrid connector in IFDN scenarios.

The dimensions should be measured according to IEC 60512-1-2 [i.4]. The plug interface of type XC hybrid connector is shown in Figure 6.1, and the dimensions should comply with Table 6.1. Figure 6.2 and Figure 6.3 show the interface for type XC hybrid connector adapters mounted on printed circuit boards and connection adapters respectively. The dimensions should comply with Table 6.2. The plug interface of type SC hybrid connector is shown in Figure 6.4, and the dimensions should comply with Table 6.3. Figure 6.5 and Figure 6.6 show the interface for type SC hybrid connector adapters mounted on printed circuit boards and connection adapters respectively. The dimensions should comply with Table 6.4.

Other optical interface dimensions and requirements should comply with IEC 60874-14-5 [i.23].

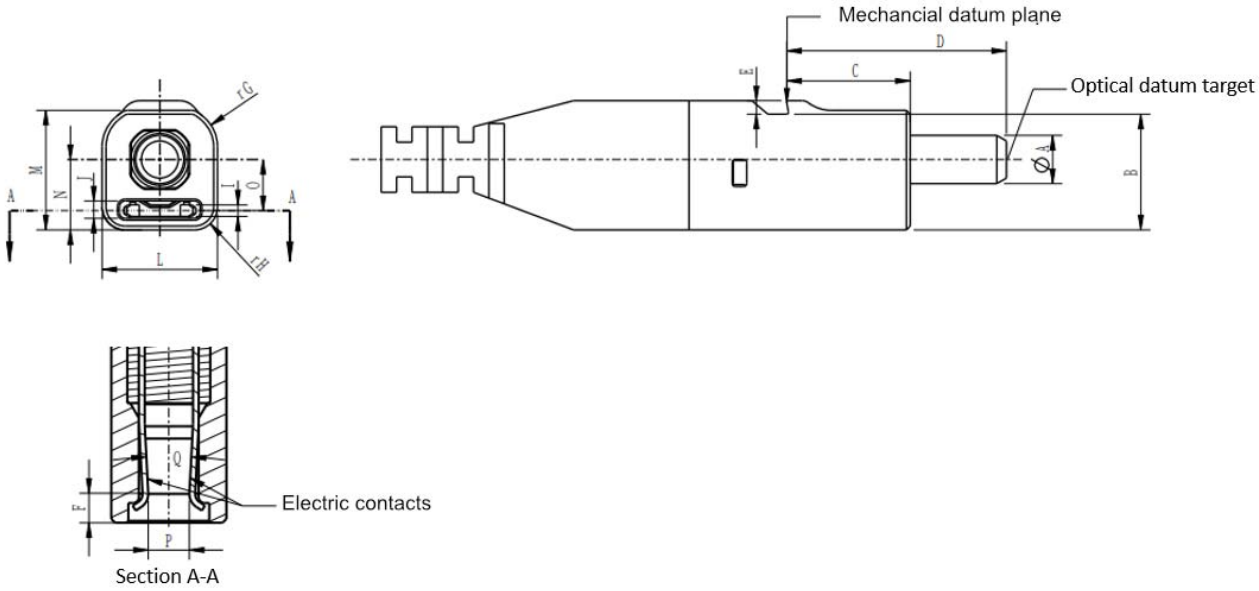


Figure 6.1: Interface for type XC hybrid plug connector

Table 6.1: Dimensions of type XC hybrid plug connector interface

Reference	Unit	Minimum	Maximum	Notes
A	mm	2,4985	2,4995	_
B	mm	5,95	6,15	_
C	mm	6,25	6,45	_
D[a]	mm	11,3	11,6	_
E	mm	0,6	0,8	_
F	mm	1,45	1,65	_
G	mm	1,2	1,4	Radius
H	mm	2	2,2	Radius
I	mm	0,6	0,8	_
J	mm	0,9	1,2	_
L	mm	5,95	6,05	_
M	mm	6,15	6,25	_
N	mm	3,6	3,7	_
O	mm	2,6	2,7	_
P	mm	2,05	2,25	_
Q	°	5	8	_
NOTE: Dimension D is based on the plug connector end face when unmated. The ferrule is moved in the direction of the contact face by the central axial pressure, so the dimension D is variable.				

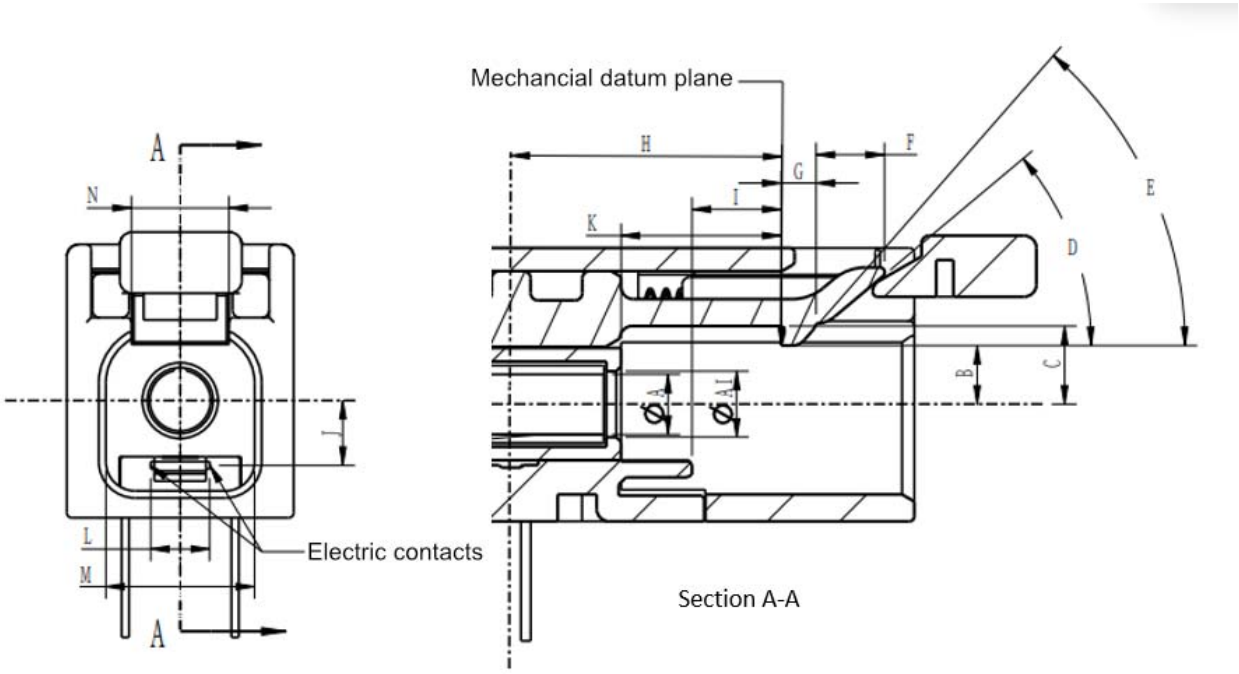


Figure 6.2: Interface for type XC hybrid connector adapters mounted on printed circuit boards

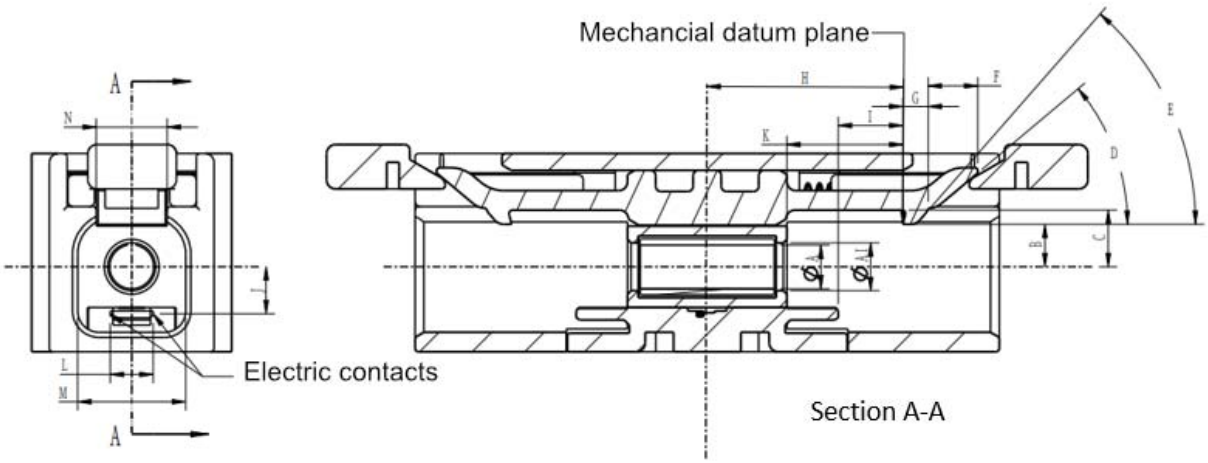


Figure 6.3: Interface for type XC hybrid connection adapters

Table 6.2: Dimensions of type XC hybrid connector adapters and connection adapters

Reference	Unit	Minimum	Maximum
A	mm	See note	See note
AI	mm	2,7	2,8
B	mm	2,3	2,5
C	mm	3,1	3,3
D	°	38	45
E	°	35	48
F	mm	2,8	3,2
G	mm	1,2	1,5
H	mm	11	11,2
I	mm	3,6	3,8
J	mm	2,6	2,7
K	mm	6,5	6,7
L	mm	2,35	2,45
M	mm	6,1	6,2
N	mm	3,8	4,2
NOTE: See table 6 in IEC 61754-4:2022 [i.43].			

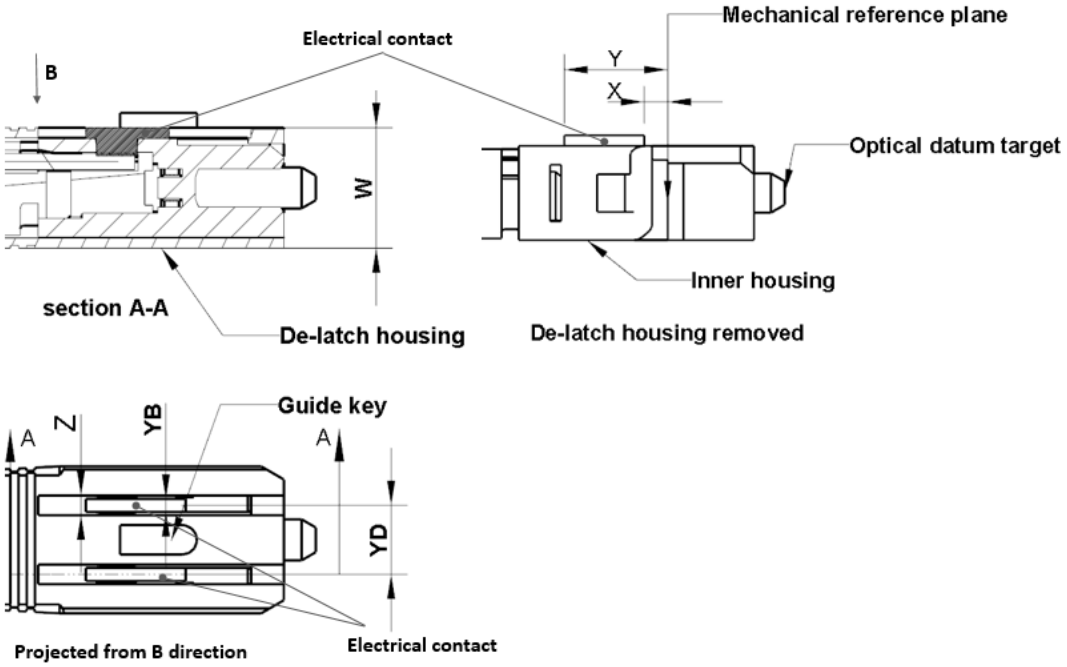


Figure 6.4: Type SC hybrid plug connector interface

Table 6.3: Dimensions of type SC hybrid plug connector interface

Reference	Unit	Minimum	Maximum	Notes
W	mm	7,29	7,39	Height dimension of the contact area after the installation of electric contacts
X	mm	-	2	Electric contact frontend relative to the mechanical datum plane
Y	mm	6,55	-	Electric contact backend relative to the mechanical datum plane
YB	mm	0,8	-	Width of the electric contact
YD	mm	4,2	4,3	Center distance between two electric contacts
Z	mm	1,3	-	Width of the through hole
NOTE: Other interface dimensions and requirements should comply with the requirements of IEC 61754-4 [i.43].				

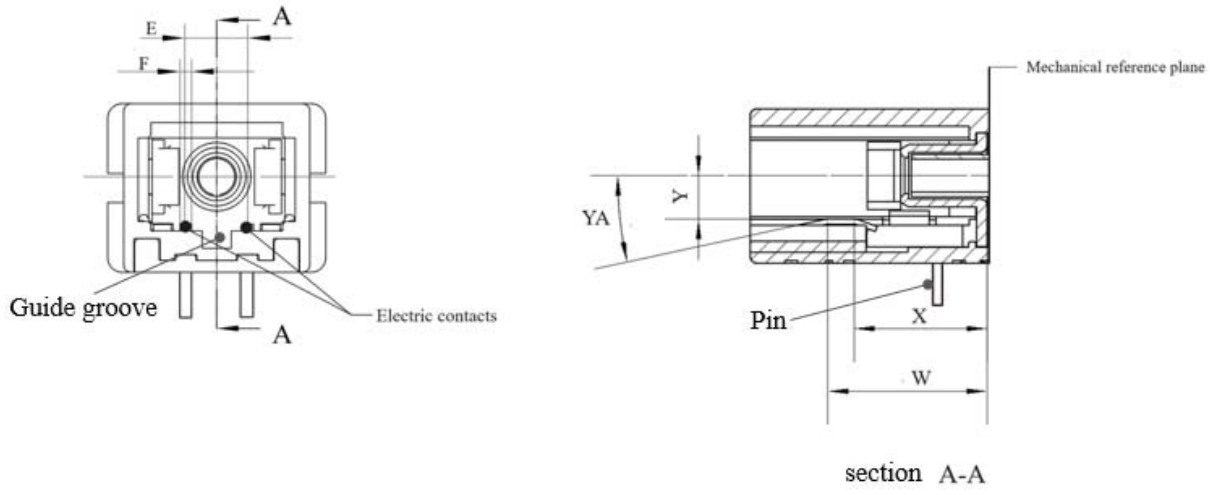


Figure 6.5: Interface for type SC hybrid adapters mounted on printed circuit boards

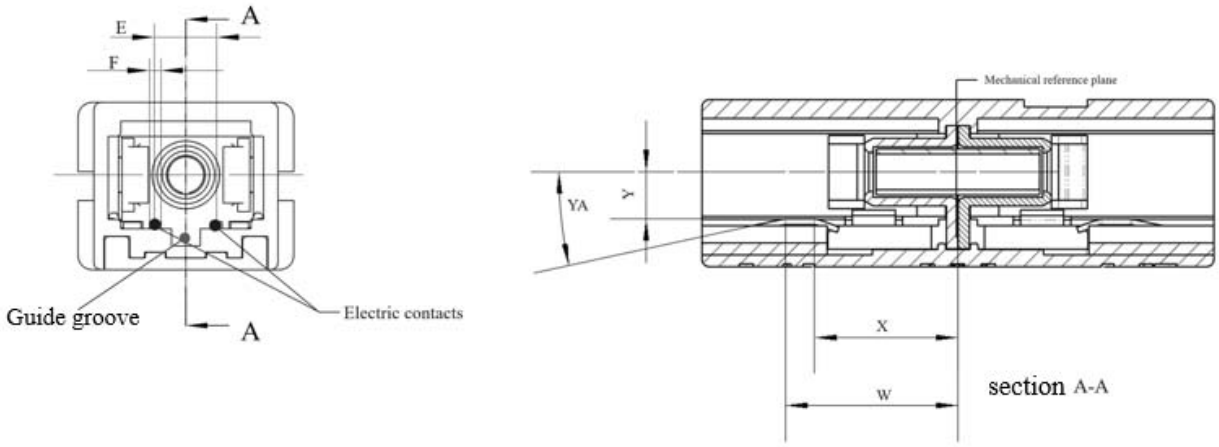


Figure 6.6: Interface for type SC hybrid connector adapters

Table 6.4: Dimensions of type SC hybrid adapters

Reference	Unit	Minimum	Maximum	Notes
E	mm	4,2	4,3	Center distance between two electric contacts
F	mm	0,8	1,2	Width of the electric contact
W	mm	12,4	-	Contact area frontend relative to the mechanical datum plane
X	mm	-	10,6	Contact area backend relative to the mechanical datum plane
Y	mm	3,3	3,4	Height dimension of the contact area plane relative to the optical datum axis
YA	°	10	15	Bending angle

6.2 Optical Transmission performance

Optical transmission performance for Hybrid connectors should conform to Table 6.5.

Table 6.5: Optical transmission performance of hybrid connectors

Test	Requirement	
Attenuation (with reference connector) IEC 61300-3-4 [i.38]	≤ 0,50 dB	
Return loss (with reference connector) IEC 61300-3-6 [i.39]	≥ 50 dB for XC/UPC hybrid connector and SC/UPC hybrid connector ≥ 60 dB for SC/APC hybrid connector	
Attenuation of random mated connector IEC 61300-3-34 [i.41] for single fibre connector	**Attenuation grades**	**Attenuation at 1 310 nm, 1 550 nm and 1 625 nm**
	Grade A	Not specified
	Grade B	⩽ 0,12 dB mean， ≤ 0,25 dB max. for ≥ 97 % of the connections
	Grade C	⩽ 0,25 dB mean， ≤ 0,50 dB max. for ≥ 97 % of the connections
	Grade D	⩽ 0,50 dB mean， ≤ 1,0 dB max. for ≥ 97 % of the connections
Random mated return loss: IEC 61300-3-34 [i.41]	**Return loss grades**	**Return loss at 1 310 nm, 1 550 nm and 1 625 nm**
	Grade 1	⩾ 60 dB (mated) and ⩾ 55 dB (unmated)
	Grade 2	⩾ 45 dB
	Grade 3	⩾ 35 dB
	Grade 4	⩾ 26 dB
Active monitoring of changes in attenuation and in return loss (multiple path) IEC 61300-3-3 [i.37]	Change in attenuation during test: δ ⩽ 0,2 dB at 1 310 nm and 1 550 nm and δ ⩽ 0,3 at 1 625 nm for pigtails (1 connection) δ ⩽ 0,5 dB at 1 310 nm, δ ⩽ 0,6 dB at 1 550 nm and δ ⩽ 0,8 dB at 1 625 nm for patch cords (= 2 connections) Change in attenuation after test: δ ⩽ 0,2 dB at 1 310 nm, 1 550 nm and 1 625 nm for pigtails (1 connection) δ ⩽ 0,4 dB at 1 310 nm, 1 550 nm and 1 625 nm for patch cords (= 2 connections)	
Transient loss: IEC 61300-3-28 [i.40]	Change in attenuation during test: δ ⩽ 0,5 dB at 1 550 nm per connection δ ⩽ 1,0 dB at 1 625 nm per connection Change in attenuation after test: δ ⩽ 0,2 dB at 1 550 nm and 1 625 nm per connection	

6.3 Electrical performance

Electrical performance for Hybrid connectors needs to conform to Table 6.6.

Table 6.6: Electrical performance of hybrid connectors

Test	Requirement	
Insulation resistance IEC 60512-3-1 [i.7]	≥ 500 MΩ	
Voltage proof IEC 60512-4-1 [i.8]	Between contacts r.m.s. withstand voltage	DC 1 000 V
	Between contacts and housing	DC 1 500 V
Contact resistance IEC 60512-2-1 [i.5]	Initial: ≤ 30 mΩ after test: rise in relation to initial values 20 mΩ max	
Active monitoring duration of discontinuities during test IEC 60512-2-5 [i.6]	≤ 1 µs	

6.4 Mechanical performance

Mechanical performance for Hybrid connectors needs to conform to Table 6.7.

Table 6.7: Mechanical performance of hybrid connectors

No.	Test	Severity	Requirement
1	Insertion and withdrawal force IEC 60512-13-2 [i.15] (For SC hybrid connector)		Total insertion force: ≤ 30 N Total withdrawal force: ≤ 30 N
2	Fibre/cable retention IEC 61300-2-4 [i.27]	Load: 50 N for 60 s	O (see note 2), V
3	Tensile strength of coupling mechanism IEC 61300-2-6 [i.29]	Load: 40 N for 60 s	O (see note 2), V
4	Flexing of the strain relief of fibre optic devices IEC 61300-2-44 [i.36]	Load: 2 N cables Cycle: ±90° Number of cycles: 50	O (see note 2), V
5	Torsion IEC 61300-2-5 [i.28]	Load: 10 N 25 cycles, ±180° Fibre/cable clamping distance: 25 cm ± 5 cm	O (see note 2), V
6	Mating durability IEC 61300-2-2 [i.26]	200 cycles No less than 3 s between engagements	O (see note 2), V

NOTE 1:
- 'O 'includes change of attenuation and return loss after the test.
- 'E' represents change of contact resistance after the test.
- 'V' represents visual examination according to IEC 60512-1-1 [i.3].

NOTE 2: Active monitoring change of attenuation during test, after the load has reached its maximum level and been stable.
NOTE 3: Active monitoring duration of discontinuities during test, after the load has reached its maximum level and been stable.
NOTE 4: Active monitoring of transient loss during test.

6.5 Environmental performance

Environmental performance for Hybrid connectors needs to conform to Table 6.8.

Table 6.8: Environmental performance of hybrid connectors

No.	Test	Severity	Criteria
1	Cold IEC 60512-11-10 [i.13]	Temperature: -10 °C Duration: 96 h	O, E, V
2	Dry heat - High temperature endurance IEC 60512-11-9 [i.12]	Temperature: +60 °C Duration: 96 h	O, E, V
3	Change of temperature IEC 60512-11-4 [i.11]	Temperature: -10 °C to +60 °C Duration: 60 min at extremes Rate of temperature change: 1 °C/min 5 cycles	O (see note 2), E, V
4	Damp heat (steady state) IEC 60512-11-12 [i.14]	Temperature: +40 °C Humidity: 93 % RH Duration: 96 h	O, E, V
5	Salt mist IEC 61300-2-26 [i.35]	Salt solution 5 % NaCl (pH: between 6,5 and 7,2) Temperature: 35 °C Duration: 48 h	O, E, V
6	Vibration (sinusoidal) IEC 60512-6-4 [i.10]	Frequency range: 10 Hz to 55 Hz Number of sweeps: 15 sweeps, (10 - 55 - 10) Hz per axis Rate of frequency change: 1 octave/min Number of axes: 3 mutually perpendicular axes Amplitude: 0,75 mm	O^{c}, E^{b}, V
7	Shock IEC 60512-6-3 [i.9]	Wave form: half sine Duration: 11 ms Acceleration: 150 m/s^2 Axes: 3 mutually perpendicular axes Number of shocks: 3 shocks per axis and per direction of axis, 18 shocks in total	O^{c}, E^{b}, V

NOTE 1:
- 'O' includes change of attenuation and return loss measurements after the test;
- 'E' includes Insulation resistance, voltage proof and change of contact resistance after the test;

No.	Test	Severity	Criteria
• 'V' represents visual examination according to IEC 60512-1-1 [i.3]. NOTE 2: Active monitoring change of attenuation during test.			

7 ADU

7.1 Structure

The structure of the ADU usually consist of the active electrical port (for power supply), optical input port (receive optical signals from the upper level), hybrid output port (transmit optical signal and electrical power together with the connected SFU), and the optional cascading optical port (transmit optical signals to the next-level ADU). The optical port and the hybrid port are connected with type SC or XC hybrid connectors.

According to the demand of application scenarios, 1:4, 1:8, and 1:16 ADU can be used in even splitting networks while 1:5 and 1:9 ADU can be used in uneven splitting networks. Typically, the ADU for uneven splitting networks contains a cascading optical port where the next level ADU can be connected, but the ADU for even splitting network only contains hybrid output port without a cascading optical port.

7.2 Operating Environment

ADU for indoor cabling system should be able to operate at following environment, according to IEC 61753-1 [i.42] category OP (Outdoor protected environment):

- Operating temperature： -25 ℃ ～ + 70 ℃
- Relative Humidity：5 % ～ 95 %；
- Atmospheric pressure：86 kPa ～ 106 kPa.

7.3 Optical Transmission Performance

Optical transmission performance for ADU is advised to conform to Table 7.1.

Table 7.1: Optical Transmission performance of ADU

Item	Splitter Ratio				
	1:5	1:9	1:4	1:8	1:16
Wavelength	1 310 nm and 1 550 nm				
Insertion Loss	Cascading optical port：≤ 11 dB Hybrid output port：≤ 11 dB	Cascading optical port：≤ 2,4 dB Hybrid output port：≤ 16,3 dB	≤ 8,2 dB	≤ 11,1 dB	≤ 14,1dB
Return Loss	≥ 50 dB				

7.4 Electrical Performance

7.4.1 Input power

The ADU operates properly with an input voltage of 45 V ~ 57 V with DC power supply.

7.4.2 Output power

The ADU output power should comply with the following requirements according to IEEE 802.3af [i.48], IEEE 802.3at [i.49], or IEEE 802.3bt [i.50] standard:

- Output voltage should be 44 V ~ 57 V DC.
- The maximum output power should depend on the number of output ports and the power consumption of SFU.
- Rated current of each output port should not be less than 0,25 A, and the rated power should not be less than 14 W.

Table 7.2: Output power performance of ADU

Level	Rated power（P）
POE (IEEE 802.3af [i.48])	P ≤ 15,4 W
POE+ (IEEE 802.3at [i.49])	P ≤ 30 W
POE++ (IEEE 802.3bt [i.50])	P ≤ 90 W

7.5 Power source protection

ADU should support the following power source protection performance:

- ADU should have indicator lamp to display the working status of each port.
- ADU should support under voltage protection function: When the input voltage is less than the voltage threshold value, ADU should turn off the output power. When the input voltage is back to the operating value, ADU should resume the working state automatically.
- ADU should support over voltage protection functions: When the input voltage is greater than the voltage threshold value, ADU should turn off the output power. When the input voltage is back to the operating value, ADU should resume the working state automatically.
- Each output port of ADU should have individual short-circuit current protection and over current protection: When the ADU detects short-circuit or over current, on one of the output ports, it should turn off the power supply on this single output port. Other ports should maintain power supply. After troubleshooting, the affected output port should resume the working state automatically.
- The ADU should be equipped with a total power protection function, such that when the total power consumption of the connected SFUs exceeds the product's maximum power capacity, the system will power off lower-priority ports based on their pre-configured port priorities, ensuring that higher-priority ports and their connected SFUs continue to operate normally.

7.6 Electrical performance

Electrical performance for ADU need to conform to Table 7.3.

Table 7.3: Electrical performance for current carrying elements

No	Test	Severity	Requirement
1	Temperature Rise Test IEC 62368-1 [i.44]	Ambient temperature: 40 °C	≤ 30 °C
2	Insulation resistance IEC 62368-1 [i.44]	Between contacts r.m.s. withstand voltage：500 V DC Duration: 60 s	≥ 500 MΩ
		Between contacts and housing： 500 V DC Duration: 60 s	

7.7 Mechanical performance

Mechanical performance for ADU should conform to Table 7.4.

Table 7.4: Mechanical performance for ADU

No	Test	Severity	Requirement
1	Shock IEC 61300-2-9 [i.30]	• ≤ 0,125 kg: 5 000 m/s^2 • 0,125 kg < Mass of the sample ≤ 0,225 kg: 2 000 m/s^2 • 0,225 kg < Mass of the sample ≤ 1 kg: 500 m/s^2 Waveforms: Half sine waveform Duration time: 1 ms Direction: Three vertical directions Times: Twice per direction, total 12 times	No mechanical damage to the appearance. Such as deformation, cracks and slackness. The optical fibre needs not to be broken, pulled out, faulty at the end or damage of the sealing. Insertion loss variation before and after test needs to be no more than 0,5 dB, and other optical performances need to conform to Table 7.1 after the test. After the test, electrical performance of ADU needs to conform to Table 7.3 when powered on.
2	Vibration (sinusoidal) IEC 61300-2-1 [i.25]	Frequency: 10 - 55 Hz Frequency scanning speed: 45 times per minute Vibration amplitude: 0,75 mm Duration: 0 min for X, Y and Z direction	

7.8 Environmental performance

Environmental performance for ADU needs to conform to Table 7.5.

Table 7.5: Environmental performance for ADU

No	Test	Severity	Requirement
1	Dry heat-High temperature IEC 61300-2-18 [i.32]	85 °C (±2 °C), duration: 96 h	No corrosion for the metal parts. No mechanical damages on the appearances, such as deformation, cracks and slackness. The optical fibre needs not to be broken, pulled out, faulty at the end or damage of the sealing. Insertion loss variation before and after test should not be no more than 0,5 dB, and other optical performances should conform to Table 7.1 after the test. After the test, electrical performance of ADU should conform to Table 7.3 when power on.
2	Cold IEC 61300-2-17 [i.31]	-40 °C (±2 °C), duration: 96 h	
3	Damp heat (steady state) IEC 61300-2-19 [i.33]	85 °C (±2 °C) 85 %（±5 %）RH, duration time: 96 h	
4	Salt mist IEC 61300-2-26 [i.35]	Salt solution 5 % NaCl (pH: between 6,5 and 7,2) Temperature: 35 °C Duration: 96 h	
5	Temperature Cycling IEC 61300-2-22 [i.34]	-40 ℃ ~ 85 °C 8 h for one-time cycle, hold highest and lowest temperature for 1 h, all cycling time is 21.	

7.9 Electromagnetic Compatibility (EMC）

ADU should support basic Electromagnetic Compatibility (EMC) function including Radiated Emission (RE), Conducted Emission (CE), Electro-Static Discharge (ESD), RF electromagnetic field (RS), Injected Currents (CS), Voltage Dips, Electrical surge, and Electrical fast transient/burst immunity. ADU should comply with the minimum EMC requirements applicable to its intended usage scenarios according to EN 55032 [i.53] and EN 55035 [i.54].

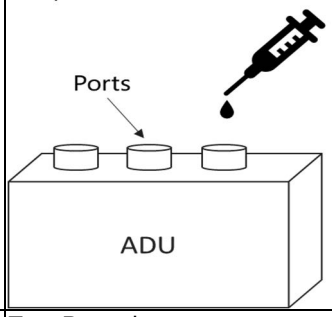
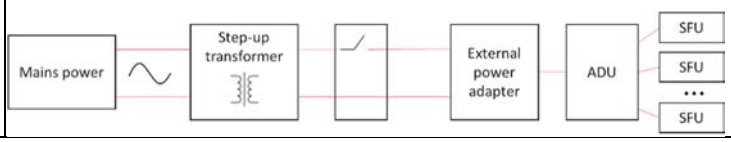
7.10 Fire safety performance

For the shell made of plastic materials, the V0 requirements should comply with UL 94 [i.52].

Fire safety tests are conducted to confirm whether the product poses fire hazards or equipment burnout risks under abnormal conditions such as abnormally high voltage or water dripping.

Fire safety performance for ADU should conform to Table 7.6.

Table 7.6: Fire safety performance for ADU

No	Test	Severity	Requirement
1	Water leakage test	The following tests are conducted on the ADU's power input port, output port, heat dissipation vents, and other openings susceptible to foreign object intrusion: 1. Connect the ADU to the main power, with all output ports connected to the SFUs via hybrid cables, ensuring the equipment operates under normal working conditions; 2. Using a syringe, slowly drip 3 ml of liquid (test separately with pure water, tap water, 5 % saline solution, and saturated saline solution) into accessible openings. Continuously monitor each location for 10 minutes to observe whether the SFU powers down, or exhibits visible flames, of a melting of the shell, etc. If such phenomena occur, halt testing; if not, proceed to the next step; 3. Drip 1 - 3 drops of liquid onto the test area, continue observation for another 10 minutes. Check again for a SFU power down or visible flames, melting of the shell, etc. If such phenomena occur, halt testing; if not, proceed to the next step; 4. Repeat Step 3 until a total testing duration of 40 minutes is completed. 	No flame out of the shell; The shell does not melt; The product shell does not exhibit carbonization.
2	Abnormal high voltage test for external power adapter	Test Procedures: 1. Connect the ADU and external power adapter to a step-up transformer, with an initial voltage of 230 V. All output ports are connected to SFUs via hybrid cables, ensuring the equipment operates under normal working conditions; 2. Adjust the step-up transformer to gradually increase the input voltage from 230 V to 253 V (the upper limit of mains power voltage fluctuations). Check whether the ADU continues to function properly. 3. At 253 V, simulate poor wiring in the household distribution box (live wire not securely connected). Repeatedly reconnect at a frequency of 1 time/second. Observe the external power adapter for shell melting, shell carbonization, or flames emitting from the shell. 4. Further adjust the step-up transformer to gradually increase the input voltage to 438 V (simulating incorrect connection to three-phase power). Power on and run the device. Check whether the ADU continues to function properly. 5. At 438 V, repeat the test described in Step 3 to observe shell melting, shell carbonization, or flames emitting from the shell under poor wiring conditions. Termination Conditions: The test stops if: 1. The housing temperature stabilizes without further increases, and no abnormalities like shell melting occur. 2. Abnormal phenomena such as shell melting, shell carbonization, or flames are observed. 	

8 Deployment

8.1 General

The IFDN hybrid cabling system is with the features including fully pre-connected, optical and electrical ports integrated, plug and play, quick deployment and reliable connection.

Before cabling, the following tools need to be prepared: optical power meter, voltage detection meter, and other auxiliary materials for construction and testing.

The cable routing personnel needs to attend training and follow operating regulations, especially the safety regulations.

8.2 Details to be noted

It is advisable to pay attention to the following items when routing cables:

- Before routing a cable, mark the labels at both ends for easy management and maintenance.
- When routing the branch cable, protect the cable and do not pull the cable with excessive force to avoid damaging the cable. Do not wind, twist, or step on the cable.
- Protect the connectors of branch hybrid cables against collision.
- Ensure that the cables are routed neatly and do not affect the unused space to facilitate capacity expansion and maintenance.
- In practice, cables can be routed in the direction from the ADU to the MFU or from the MFU to the ADU based on the site environment to ensure that optical cables are easy to coil.
- When routing and securing cables, straighten the cables every 5 m. The bending radius of cables should be no less than 24 mm.
- Strong-current and weak-current cables are advised to be routed separately and far away from heat sources. If there are mice, PVC pipes should be used to protect the cables, and rodent-proof measurements should be taken in the surrounding environment.
- When passing through concealed pipes, pay attention to the old cables or network cables in the pipes which have taken too much space, and avoid excessive pulling force during wiring in case the connectors could be pulled off.
- Before threading the tube, try to remove sharp and hard objects in the tube to avoid friction and cracking of the cable sheath. Besides, the environment inside the tube should be clean and dry in case of the corrosion damage to the cables.
- When threading the pipe, stress the cable rather than the connector.
- Keep the cable laid out in a good ventilation and heat dissipation environment rather than placing the remaining length of the coil directly near the heat source during deployment.

8.3 Acceptance items

8.3.1 Electrical performance acceptance

During the cable routing, the ADU need not work and affect the remote power supply. The following method can be used to verify the issue:

1) Route the cables, and connect the other end of the hybrid connector to the voltage detection meter as described in Figure 8.1.
2) Turn on the ADU to check if the light of normal work status is on.

3) Test the voltage between the positive and negative PIN poles to verify if it is within the normal voltage ranges.

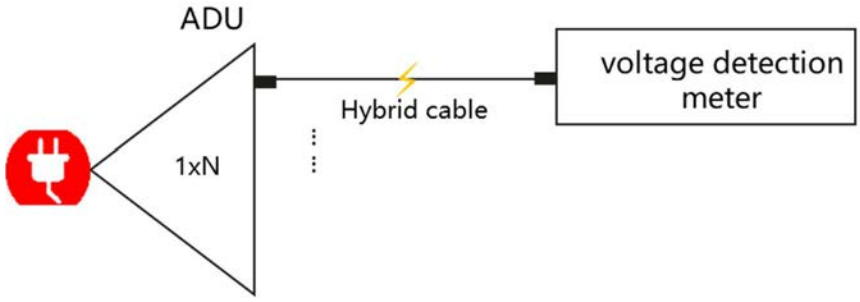


Figure 8.1: Schematic diagram of the electrical performance acceptance test

8.3.2 Optical power acceptance

During the cable routing, the cable might be broken or severely bent. As a result, the optical power loss is severe and the insertion loss increases. The following method can be used to verify the issue:

a) Route the cables, and connect an Adapter, a patch cord and an optical power meter as described in Figure 8.2.

b) Measure and record the optical power of the ADU and hybrid cable.

c) Check if the optical power can meet the receiving sensitivity index of SFU.

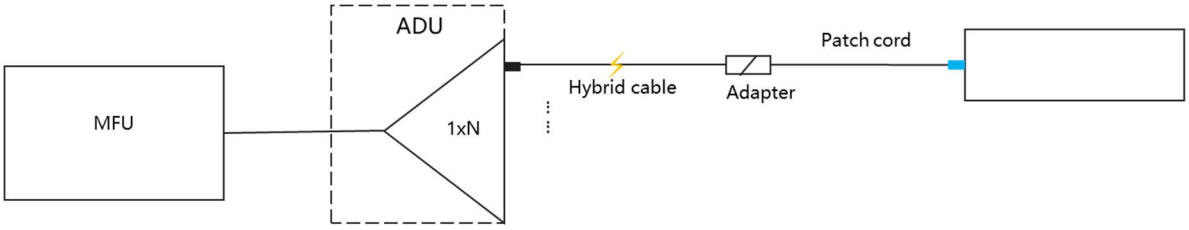


Figure 8.2: Schematic diagram of the Optical power acceptance test

Annex A: Biobliography

- IEC 61076-3-127: "Connectors for Electrical and Electronic Equipment - Product Requirements - Part 3-127: Rectangular connectors - Detail specification for hybrid connectors with 2-pole 2,0 A max, 60 V DC electric portion for power supply and type XC fibre optic portion for data transmission".
- IEC 61076-3: "Connectors for Electrical and Electronic Equipment - Product Requirements - Part 3-123 Rectangular connectors - Detail specification for hybrid connectors with 2-pole 2,0 A max, 60 V DC electric portion for power supply and type SC fibre optic portion for data transmission, with push-pull locking".

History

Version	Date	Status
V1.1.1	October 2025	Publication