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Responsible committee: EPL/46 Cables, wires and waveguides, radio frequency connectors and accessories for communication and signalling

Interested committees:

Title: BS EN IEC 61935-4 Specification for the testing of balanced and coxial information technology cabling

Part 4: Installed balanced single pair cabling as specified in ISO/IEC 11801-1 and related standards

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## Introduction

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For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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## Template for comments and secretariat observations

|                  |                        |
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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/Figure/ Table/Note | Type of comment | Commend (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



46/998/CD

COMMITTEE DRAFT (CD)

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IEC TC 46 : CABLES, WIRES, WAVEGUIDES, RF CONNECTORS, RF AND MICROWAVE PASSIVE COMPONENTS AND ACCESSORIES

SECRETARIAT:

United States of America

SECRETARY:

Mr David Hess

OF INTEREST TO THE FOLLOWING COMMITTEES:

SC 46A, SC 46C

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

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☐ ENVIRONMENT

☒ QUALITY ASSURANCE

☐ SAFETY

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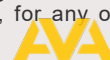
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TITLE:

**Specification for the testing of balanced and coxial information technology cabling- Part 4: Installed balanced single pair cabling as specified in ISO/IEC 11801-1 and related standards**

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

SPECIFICATION FOR THE TESTING OF BALANCED AND  
COAXIAL INFORMATION TECHNOLOGY CABLING –Part 4: Installed balanced single-pair cabling as specified in ISO/IEC  
11801-1 and related standards

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IEC 61935-4 has been prepared by IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

The text of this International Standard is based on the following documents:

| Draft        | Report on voting |
|--------------|------------------|
| 46/XXXX/FDIS | 46/XXXX/RVD      |

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

- 229 The language used for the development of this International Standard is **English**.
- 230 This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in  
231 accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available  
232 at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are  
233 described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).
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236 specific document. At this date, the document will be
- 237 • reconfirmed,
  - 238 • withdrawn, or
  - 239 • revised.
- 240

241

## INTRODUCTION

242 Telecommunication cabling, once specified uniquely by each telecommunications application,  
243 has evolved into a generic cabling system including single-pair cabling systems.  
244 Telecommunications applications use the ISO/IEC 11801-1 cabling standard to meet their  
245 cabling requirements. Formerly, connectivity tests and visual inspection were deemed sufficient  
246 to verify a cabling installation. Users need more comprehensive testing in order to ensure that  
247 the link will support telecommunications applications that are designed to operate on the  
248 generic cabling system. This part of IEC 61935 addresses reference laboratory and field test  
249 methods and provides a comparison of these methods.

250 Transmission performance depends on cable characteristics, connecting hardware, patch cords  
251 and cross-connect cabling, the total number of connections and the care with which they are  
252 installed and maintained. IEC 61935 (all parts) provides test methods for installed cabling and  
253 pre-fabricated cable assemblies. These test methods, where appropriate, are based on those  
254 used for components of the cable assembly.

255 This Part 4 contains the test methods required for laboratory testing and testing of installed  
256 single twisted pair cabling.

257 Since part 4 often refers back to IEC 61935-1 for further details, the document structure of part  
258 4 has been kept the same as IEC 61935-1 to make the document easier to understand and  
259 follow.

## SPECIFICATION FOR THE TESTING OF BALANCED AND COAXIAL INFORMATION TECHNOLOGY CABLING –

### Part 4: Installed balanced single-pair cabling as specified in ISO/IEC 11801-1 and related standards

#### 1 Scope

This part of IEC 61935 specifies reference measurement procedures for balanced single-pair cabling parameters and the requirements for field tester accuracy to measure cabling parameters identified in ISO/IEC 11801-1. References in this standard to ISO/IEC 11801-1 mean ISO/IEC 11801-1 or equivalent cabling standards.

This standard is organized as follows:

- reference laboratory measurement procedures on cabling topologies are specified in clause 4. In some cases, these procedures may be used in the field;
- descriptions and requirements for measurements in the field are specified in clause 5;
- performance requirements for field testers and procedures to verify performance are specified in clause 6.

NOTE 1 This standard does not include tests that are normally performed on cables and connectors separately. Tests performed on cables and connectors are described in IEC 61156-1 and IEC 60512-28-100, respectively.

NOTE 2 Users of this standard are advised to consult with applications standards, equipment manufacturers and system integrators to determine the suitability of these requirements for specific networking applications.

Wherever possible, cables and connectors used in cable assemblies, even if they are not described in the IEC 61156 or the IEC 63171 series, they should be tested separately according to the parameters given in the ISO/IEC 11801 series. In this case most of the environmental and mechanical tests described in this standard may be omitted.

This standard is based on cabling with a characteristic impedance of 100  $\Omega$ . For cabling with another characteristic impedance, the same principles apply but the measurement system should correspond to the nominal characteristic impedance level.

Field tester types include certification, qualification and verification test equipment.

Certification testing is performed to the requirements of this standard.

Qualification testing determines whether the cabling will support certain network applications (e.g. 10BASE-T1L, 100BASE-T1, 1000BASE-T1, 2.5G/5G/10GBASE-T1). Qualification testers do not have traceable accuracy to national standards and only provide confidence that specific applications will work.

Verification testers only verify connectivity.

#### 2 Normative reference

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60169-15, *Radio-frequency connectors – Part 15: R.F. coaxial connectors with inner diameter of outer conductor 4.13 mm (0.163 in) with screw coupling – Characteristic impedance 50 ohms (Type SMA)*

- 303 IEC 60169-22, *Radio-frequency connectors – Part 22: R.F. two-pole bayonet coupled*  
304 *connectors for use with shielded balanced cables having twin inner conductors (Type BNO)*
- 305 IEC 60512-25-9, *Connectors for electronic equipment – Tests and measurements – Part 25-9:*  
306 *Signal integrity tests – Test 25i: Alien crosstalk*
- 307 IEC 60512-28-100, *Connectors for electrical and electronic equipment - Tests and*  
308 *measurements - Part 28-100: Signal integrity tests up to 2 000 MHz - Tests 28a to 28g*
- 309 IEC 63171 Series *Connectors for electrical and electronic equipment - Shielded or unshielded*  
310 *free and fixed connectors for balanced single-pair data transmission with current-carrying*  
311 *capacity - General requirements and tests*
- 312 IEC 61156-1, *Multicore and symmetrical pair/quad cables for digital communications – Part 1:*  
313 *Generic specification*
- 314 IEC TS 61156-1-2, *Multicore and symmetrical pair/quad cables for digital communications –*  
315 *Part 1-2: Electrical transmission characteristics and test method of symmetrical pair/quad*  
316 *cables*
- 317 IEC 61156-11 *Multicore and symmetrical pair/quad cables for digital communications - Part 11:*  
318 *Symmetrical single-pair cables with transmission characteristics up to 600 MHz - Horizontal*  
319 *floor wiring - Sectional specification*
- 320 IEC 61156-12 *Multicore and symmetrical pair/quad cables for digital communications - Part 12:*  
321 *Symmetrical single-pair cables with transmission characteristics up to 600 MHz - Work area*  
322 *wiring - Sectional specification*
- 323 IEC 61156-13 *MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL*  
324 *COMMUNICATIONS - Part 13: Symmetrical single-pair cables with transmission characteristics*  
325 *up to 20 MHz - Horizontal floor wiring - Sectional specification*
- 326 IEC 61156-14:2024<sup>1</sup>, *MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL*  
327 *COMMUNICATIONS. Part 14: Symmetrical single pair cables with transmission characteristics*  
328 *up to 20MHz. Work area wiring – Sectional specification*
- 329 IEC 61169-15:2021 ED1 *Radio-frequency connectors - Part 15: Sectional specification - RF coaxial*  
330 *connectors with inner diameter of outer conductor 4,13 mm (0,163 in) with threaded coupling -*  
331 *Characteristic impedance 50 Ω (type SMA)*
- 332 IEC 61935-1-2 *Specification for the testing of balanced communication cabling in accordance*  
333 *with ISO/IEC 11801-1 – Part 1-2: additional requirements for measurement of resistance*  
334 *unbalance with field test instrumentation*
- 335 IEC 62153-4-9, *Metallic communication cable test methods – Part 4-9: Electromagnetic*  
336 *compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method*
- 337 IEC 62153-4-11, *Metallic communication cable test methods – Part 4-11: Electromagnetic*  
338 *compatibility (EMC) – Coupling attenuation or screening attenuation of patch cords, coaxial*  
339 *cable assemblies, pre-connectorized cables – Absorbing clamp method*
- 340 IEC 62153-4-14, *Metallic communication cable test methods – Part 4-14: Electromagnetic*  
341 *compatibility (EMC) – Coupling attenuation of cable assemblies (Field conditions) absorbing*  
342 *clamp method*

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<sup>1</sup> Under preparation. Stage at the time of publication: CDV xxxx:2024.

ISO/IEC 11801-1, *Information technology – Generic cabling for customer premises*

ISO/IEC 14763-1, *Information technology – Implementation and operation of customer premises cabling – Part 1: Administration*

ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

### 3 Terms, definitions and abbreviations

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1 Acronyms

SP single-pair

### 4 Reference measurement procedures for electrical properties

#### 4.1 General

Clause 4 describes reference measurement procedures for electrical parameters. The measurement procedures are intended to be used in a laboratory environment using laboratory equipment. In some cases, a measurement procedure may also be applicable for field testing. If this is the case, the procedure shall be specifically identified as being suitable for installed cabling and appropriate precautions shall be described.

Unless otherwise specified all measurement considerations shall be according to IEC 61935-1.

**Table 1 – Accuracy levels and frequency ranges**

| Level  |  | Frequency range [MHz] |
|--------|--|-----------------------|
| SP-I   |  | 0,1 – 20              |
| SP-II  |  | 0,1 – 600             |
| SP-III |  | 0,1 - 1250            |

#### 4.2 Common measurement considerations

##### 4.2.1 Test equipment consideration

For test equipment considerations refer to IEC 61935-1.

##### 4.2.2 Network analyser test requirements

Usually the input and output terminals of a network analyser are unbalanced. RF transformers with balanced outputs (baluns) can be used with unbalanced signal connections to the network analyser. For balunless test adapters, refer to IEC TS 61156-1-2. Balunless test adapters are particularly suitable for mixed mode measurements.

##### 4.2.3 Test set-up

For test setups refer to IEC 61935-1.

#### 4.2.4 Termination of conductor pairs

During measurement, all conductor pairs of the cabling under test shall be terminated at both ends with impedance matching loads. For pairs under test, this is provided by the test instrumentation at one or both ends. For pairs not under test or not connected to test instrumentation, resistor loads or terminated baluns shall be applied.

Unless otherwise specified, the nominal differential mode impedance of the termination shall be 100  $\Omega$  for 100  $\Omega$  cabling. The nominal common mode impedance shall be nominal 50  $\Omega$ , unless otherwise specified in the measurement procedure.

Resistor loads shall use resistors specified for  $\pm 0,1$  % accuracy at DC and have a return loss of 46 dB up to 100 MHz and 40 dB up to the maximum frequency. For pairs connected to a balun, a common mode load is implemented by applying a load at the centre tap of the balun. The impedance of the load is equal to the common mode impedance. The common mode impedance is approximately one fourth of the differential mode impedance for this implementation. For pairs connected to resistor loads, common mode load is implemented by the Y configuration shown in Figure 1.

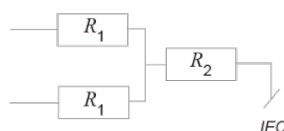


Figure 1 – Resistor load

where

$$R_1 = \frac{R_{dif}}{2} \quad (1)$$

$$R_1 = 50 \, \Omega \pm 0,1 \, \%$$

and

$$R_2 = R_{com} - \frac{R_{dif}}{4} \quad (2)$$

$$R_2 = 25 \, \Omega \pm 1 \, \%$$

where

$R_{dif}$  is the differential mode resistance ( $\Omega$ );

$R_{com}$  is the common mode resistance ( $\Omega$ ).

For unscreened cabling, the common mode termination point for the pair is the ends of the wires connected together and to the ground at either end of the cabling. For screened cabling, the common mode termination point is connected to the cable screen and ground at each end of the cabling.

NOTE Accuracy is dependent on the uses of equivalent calibration techniques.

#### 4.2.5 Reference loads for calibration

To perform reference plane calibration of the test equipment, the following devices shall be used:

- 1-port calibration: a short circuit, an open circuit and an impedance matching reference load;

- 2-port calibration: as above, plus a through artefact.

The impedance matching termination shall be calibrated against a calibration reference, which shall be a 50  $\Omega$  load, traceable to a national reference standard. If the value of the reference load for calibration is 100  $\Omega$ , two loads in parallel shall be calibrated against the calibration reference. The reference loads for calibration shall be placed in an SMA type connector according to IEC 60169-15, pin type for cable mounting, in which the load is enclosed on the cable end. A network analyser shall be calibrated, one port full calibration, with the calibration reference. Thereafter, the return loss of the reference loads for calibration shall be measured. The verified return loss shall be 46 dB up to 100 MHz and 40 dB up to the maximum frequency.

#### **4.2.6 Test configurations**

Balanced single-pair cabling configurations as per ISO/IEC 11801-1 shall be supported.

#### **4.2.7 Coaxial cables and test leads for network analysers**

For coaxial cables and test leads for network analysers refer to IEC 61935-1.

#### **4.2.8 Balanced test leads**

Balanced test leads and associated connecting hardware to connect between the test equipment and the cable assembly under test shall be taken from components that meet or exceed the requirements for the category of the cable assembly under test. Balanced test leads shall be limited to a length of 50 mm between any test fixtures and the reference plane of the cabling under test. Pairs shall remain twisted between any test fixtures to where connections are made to the DUT, and unscreened balanced test leads shall be separated by 5 mm from any ground plane.

#### **4.2.9 Balun requirements**

Depending on the test set-up, baluns are an optional element that may be required for measurements. In case baluns are used, the following applies:

Baluns shall be RFI shielded and shall comply with the requirements given in Table 2.

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**Table 2 Test balun performance characteristics (TBD)**

| Parameter/class                                 | Class SP-1               | Class SP-1                                             | Class SP-1                                                                            |
|-------------------------------------------------|--------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------|
| Frequency range                                 | 0,1 to 20 MHz            | 0,1 to 600 MHz                                         | 0,1 to 1250 MHz                                                                       |
| Impedance, primary <sup>a</sup>                 | 50 $\Omega$ unbalanced   | 50 $\Omega$ unbalanced                                 | 50 $\Omega$ unbalanced                                                                |
| Impedance, secondary                            | Matched balanced         | Matched balanced                                       | Matched balanced                                                                      |
| Insertion loss <sup>d</sup> , maximum           | 3 dB                     | 3 dB                                                   | 3 dB                                                                                  |
| Return loss secondary, minimum                  | 12 dB, 0,1 MHz to 20 MHz | 12 dB, 0,1 MHz to 15 MHz<br>20 dB, 15 MHz to 600 MHz   | 12 dB, 0,1 MHz to 15 MHz<br>20 dB, 15 MHz to 600 MHz<br>10 dB, 600 MHz to 1 250 MHz   |
| Return loss, common mode <sup>b</sup> , minimum | 12 dB, 0,1 MHz to 20 MHz | 12 dB, 0,1 MHz to 15 MHz<br>20 dB, 15 MHz to 600 MHz   | 12 dB, 0,1 MHz to 15 MHz<br>20 dB, 15 MHz to 600 MHz<br>10 dB, 600 MHz to 1 250 MHz   |
| Power rating                                    | 0,1 Watt minimum         | 0,1 Watt minimum                                       | 0,1 Watt minimum                                                                      |
| Longitudinal balance <sup>c</sup> , minimum     | 60 dB, 0,1 MHz to 20 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz<br>40 dB, 600 MHz to 1 250 MHz |
| Output signal balance <sup>c</sup> , minimum    | 60 dB, 0,1 MHz to 20 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz<br>40 dB, 600 MHz to 1 250 MHz |
| Common mode rejection <sup>c</sup> , minimum    | 60 dB, 0,1 MHz to 20 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz | 60 dB, 0,1 MHz to 400 MHz<br>50 dB, 400 MHz to 600 MHz<br>40 dB, 600 MHz to 1 250 MHz |

NOTE Proper test for configurations for qualifying tests baluns to the requirements are given in Annex D.

#### 4.2.10 Balunless

Where balunless techniques are used for measurement, the requirements are provided by IEC TS 61156-1-2, IEC 60512-28-100, and shall be applied to the full frequency range of the test.

#### 4.2.11 Network analyser measurement precautions

For network analysers measurement precautions refer to IEC 61935-1.

#### 4.2.12 Data reporting and accuracy

The measurement uncertainty shall be determined for each test. This shall be calculated by determining the uncertainty from each error source expressed as the resulting spread in the result. The values of the different error sources are based on instrumentation specifications, calculated errors from imperfect calibration loads and measurement experience. The overall estimated measurement uncertainty is calculated as two times the resulting spread coming from the different error sources. The resulting spread is calculated as:

$$\sigma \sqrt{\sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2} \quad (3)$$

where  $\sigma_1$  to  $\sigma_n$  is the spread of the different error sources.

The overall measurement uncertainty is defined as  $2\sigma_{res}$  which is approximately equivalent to a 95 % confidence level. A measurement uncertainty band is determined on both sides of the specified limit.

#### 4.2.13 Frequency step size

Unless otherwise specified, if the test instrument measures at discrete frequencies, the frequency steps shall be no greater than:

- 20 kHz from 0,1 MHz up to 20 MHz
- 150 kHz from 20 MHz up to 31,25 MHz;
- 250 kHz from 31,25 MHz up to 100 MHz;
- 500 kHz from 100 MHz up to 250 MHz;
- 1 MHz from 250 MHz up to 600 MHz;
- 2 MHz from 600 MHz up to 1 250 MHz.

#### 4.2.14 Mixed Mode S-parameters measurements

The S-parameters of a mixed mode measurement consist of 16 terms for a single measurement path, providing the full matrix of common and differential parameters. The nomenclature is given by Table 3.

**Table 3 –Mixed mode S-parameter nomenclature**

|                            |        | Differential mode stimulus |            | Common mode stimulus |            |
|----------------------------|--------|----------------------------|------------|----------------------|------------|
|                            |        | Port 1                     | Port 2     | Port 1               | Port 2     |
| Differential mode response | Port 1 | $S_{DD11}$                 | $S_{DD12}$ | $S_{DC11}$           | $S_{DC12}$ |
|                            | Port 2 | $S_{DD21}$                 | $S_{DD22}$ | $S_{DC21}$           | $S_{DC22}$ |
| Common mode response       | Port 1 | $S_{CD11}$                 | $S_{CD12}$ | $S_{CC11}$           | $S_{CD12}$ |
|                            | Port 2 | $S_{CD21}$                 | $S_{CD22}$ | $S_{CC21}$           | $S_{CC22}$ |

#### 4.3 DC loop resistance

For DC loop resistance measurements refer to IEC 61935-1.

Note that drawings in IEC 61935-1 show a DC loop resistance measurements on a 4 pair cabling. Same test setup is applicable for single-pair cabling as well.

#### 4.4 Direct current (DC) resistance unbalance

EDITORS NOTE: this paragraph is FFS, propose undated reference to 61935-1

EDITORS NOTE: Reference to IEC 61935-1-2, with accuracy FFS

##### 4.4.1 Objective

The objective of this test is to ensure the DC resistance unbalance meets the requirements.

##### 4.4.2 Test method

Test methods shall be in accordance with IEC 61935-1-2.

Note that drawings in IEC 61935-1 clause 4.4.2 show measurements on 4 pair cabling. Same test setup is applicable for single-pair cabling as well.

##### 4.4.3 Test equipment and set-up

Test equipment and set-up shall be in accordance with IEC 61935-1.

##### 4.4.4 Procedure

Test procedure shall be in accordance with IEC 61935-1.

#### 4.5 Direct current (DC) resistance unbalance between pairs

This test is not applicable for SP cabling.

#### 4.6 Insertion loss

For objective, test method, test equipment and set-up, and procedure shall be in accordance with IEC 61935-1.

Note that drawings in IEC 61935-1 show measurements on 4 pair cabling. Same test setup is applicable for single-pair cabling as well.

##### 4.6.1 Temperature correction

The temperature coefficient for screened cabling is 0,2 %/°C. For unscreened cabling, the temperature coefficient is specified to be maximum 0,4 %/°C below between 20 °C and 40 °C and 0,6 %/°C between 40 °C and 60 °C, see IEC 61156-11, IEC 61156-12, IEC 61156-13 and IEC 61156-14.

##### 4.6.2 Uncertainty

The uncertainty of reference insertion loss measurements for cabling shall be less than 0,5 dB/100 m.

EDITORS NOTE: to be verified if this is still achievable with SP cabling

#### 4.7 Propagation delay

##### 4.7.1 Objective

The objective of this test is to measure propagation delay of the cabling being tested.

The test method is applicable to cabling in a laboratory environment only. The reference test method cannot be used for installed cabling.

## 4.7.2 Test method

Propagation delay is measured by determining the phase delay of a signal transmitted through the cabling using Equation (3).

$$\delta = \frac{\varphi}{2\pi f} \quad (3)$$

where

$\delta$  is the phase delay in seconds;

$\varphi$  is the phase in radians;

$f$  is the frequency in Hertz.

## 4.7.3 Test equipment and set-up

The set-up is the same as for insertion loss measurements (see 4.6.3). Insertion loss and delay can be measured in the same test with one sweep if the network analyser can measure the complex scattering parameter,  $S_{21}$ .

## 4.7.4 Procedure

### 4.7.4.1 Calibration

See 4.6.4.1.

### 4.7.4.2 Measurement

See 4.6.4.2, but note that for this measurement a linear frequency sweep shall be applied. The frequency steps shall be made small enough to ensure that the phase shift from one measurement frequency to the next measurement frequency is less than  $2\pi$ . In order to assure an adequate margin, the frequency steps shall be no greater than 1 MHz.

### 4.7.4.3 Calculation

Some network analysers give a readout of the continuous phase trace of the tested item. This readout can be directly inserted in Equation (4). It is usual for the network analyser to measure the phase in an interval of  $\pm\pi$ . As the ratio of phase versus frequency is a continuously decreasing function,  $2\pi$  shall be subtracted from the measured phase every time there is a positive step in the measured phase versus frequency trace, therefore:

$$\varphi_f = \varphi_m \quad (4)$$

where

$\phi_f$  is the accumulated phase in degrees;

$\phi_m$  is the measured phase in degrees;

$n$  is the number of times the measured phase has passed  $-\pi$  during the measurement from the lowest frequency to the actual frequency  $f$ .

The propagation delay is calculated by applying Equation (4).

## 4.7.5 Test report

Propagation delay is reported at 10 MHz. Results at other frequencies shall be reported, if required in the relevant sectional specification.

#### 4.7.6 Uncertainty

Uncertainty of reference propagation delay measurements shall be less than 2,5 ns (TBD) in the range of 0 ns to 9000 ns.

#### 4.8 Near-end cross-talk (NEXT) and power sum NEXT

There are no requirements for this parameter for balanced single-pair cabling. The paragraph is still present in this standard to keep consistency with IEC 61935-1.

#### 4.9 Attenuation to crosstalk ratio, near end (ACR-N) and power sum ACR-N

There are no requirements for this parameter for balanced single-pair cabling. The paragraph is still present in this standard to keep consistency with IEC 61935-1.

#### 4.10 Far-end cross-talk (FEXT) and power sum FEXT

There are no requirements for this parameter for balanced single-pair cabling. The paragraph is still present in this standard to keep consistency with IEC 61935-1.

#### 4.11 Attenuation to crosstalk ratio, far end (ACR-F)

There are no requirements for this parameter for balanced single-pair cabling. The paragraph is still present in this standard to keep consistency with IEC 61935-1.

#### 4.12 PS alien near end crosstalk (PS ANEXT – Exogenous crosstalk)

**EDITORS NOTE: if no changes are made to this clause, replace content with reference to IEC 61935-1.**

##### 4.12.1 Objective

The objective of this test is to determine the PS ANEXT of the cabling. This test is applicable to cabling in a laboratory environment and for installed cabling. A sample laboratory reference measurement assembly is described in Annex B.

##### 4.12.2 Test method

ANEXT contributions to an overall PS ANEXT are measured by applying the signal at the near end to one pair to a disturbing link and measuring the coupled signal at the near end of a pair in a disturbed link. This process is repeated for every pair in a disturbing link and for all other links in close proximity. The PS ANEXT for each pair in a disturbed link is obtained by power summing the ANEXT results to that pair from all pairs in disturbing links in close proximity.

##### 4.12.3 Test equipment and set-up

The test configuration for an alien near end crosstalk measurement is shown in Figure 2. The cabling under test shall be measured at the reference planes shown in Figure 2