

INTERNATIONAL STANDARD



Radio frequency and coaxial cable assemblies – Part 1: Generic specification – General requirements and test methods



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.



IEC 60966-1

Edition 3.0 2019-02
REDLINE VERSION

INTERNATIONAL STANDARD



Radio frequency and coaxial cable assemblies – Part 1: Generic specification – General requirements and test methods

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.120.10

ISBN 978-2-8322-6560-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
1 Scope.....	9
2 Normative references	9
3 Terms and definitions	9
4 Design and manufacturing requirements.....	13
4.1 Cable design and construction	13
4.2 Connector design and construction	13
4.3 Outline and interface dimensions	13
5 Workmanship, marking and packaging.....	13
5.1 Workmanship	13
5.2 Marking.....	14
5.3 End caps.....	14
5.4 Packaging and labelling	14
6 ~~Quality assessment~~ management	14
7 Test methods – General	14
7.1 Standard atmospheric conditions for testing.....	14
7.2 Visual inspection.....	15
7.3 Dimensions inspection	15
7.3.1 Interface dimensions	15
7.3.2 Outline dimensions	15
8 Electrical tests.....	15
8.1 Reflection properties.....	15
8.1.1 Object.....	15
8.1.2 Test equipment	15
8.1.3 Procedure.....	16
8.1.4 Requirements	16
8.1.5 Information to be given in the detail specification.....	16
8.2 Uniformity of impedance	17
8.2.1 Object.....	17
8.2.2 Procedure.....	17
8.2.3 Requirements	17
8.2.4 Information to be given in the detail specification.....	17
8.3 Insertion loss	17
8.3.1 Procedure.....	17
8.3.2 Requirements	17
8.3.3 Information to be given in the detail specification.....	17
8.4 Insertion loss stability	17
8.4.1 Object.....	17
8.4.2 Procedure.....	17
8.4.3 Requirements	17
8.4.4 Information to be given in the detail specification.....	17
8.5 Propagation time.....	18
8.5.1 Procedure.....	18
8.5.2 Requirements	18
8.5.3 Information to be given in the detail specification.....	18

8.6	Stability of electrical length	18
8.6.1	Object.....	18
8.6.2	Procedures	18
8.6.3	Requirements	21
8.6.4	Information to be given in the detail specification	22
8.7	Phase difference	22
8.7.1	Object.....	22
8.7.2	Procedure.....	22
8.7.3	Requirements	22
8.7.4	Information to be given in the detail specification	22
8.8	Phase variation with temperature	22
8.8.1	Object.....	22
8.8.2	Procedure.....	22
8.8.3	Requirements	22
8.8.4	Information to be given in the detail specification	22
8.9	Screening effectiveness	23
8.9.1	Transfer impedance	23
8.9.2	Screening attenuation	23
8.10	Voltage proof	23
8.10.1	Procedure.....	23
8.10.2	Requirements	23
8.10.3	Information to be given in the detail specification	23
8.11	Insulation resistance	24
8.11.1	Procedure.....	24
8.11.2	Requirements	24
8.11.3	Information to be given in the detail specification	24
8.12	Inner and outer conductor continuity	24
8.12.1	Object.....	24
8.12.2	Procedure.....	24
8.12.3	Requirements	24
8.12.4	Information to be given in the detail specification	24
8.13	Power rating	24
8.13.1	Object.....	24
8.13.2	Procedure.....	25
8.13.3	Requirements	25
8.13.4	Information to be given in the detail specification	25
8.14	Intermodulation level measurement.....	25
8.14.1	Procedure.....	25
8.14.2	Requirements	25
8.14.3	Information to be given in the detail specification	25
9	Mechanical robustness tests.....	25
9.1	Tensile.....	25
9.1.1	Object.....	25
9.1.2	Procedure.....	26
9.1.3	Requirements	26
9.1.4	Information to be given in the detail specification	26
9.2	Flexure	26
9.2.1	Object.....	26
9.2.2	Procedure.....	26

9.2.3	Requirements	27
9.2.4	Information to be given in the detail specification	27
9.3	Flexing endurance	27
9.3.1	Object.....	27
9.3.2	Procedure.....	27
9.3.3	Requirements	28
9.3.4	Information to be given in the detail specification	28
9.4	Cable assembly crushing	28
9.4.1	Object.....	28
9.4.2	Procedure.....	28
9.4.3	Requirements	29
9.4.4	Information to be given in the detail specification	29
9.5	Torque	30
9.5.1	Procedure.....	30
9.5.2	Requirements	30
9.5.3	Information to be given in the detail specification	30
9.6	Multiple bending.....	30
9.6.1	Object.....	30
9.6.2	Procedure.....	30
9.6.3	Requirements	31
9.6.4	Information to be given in the detail specification	31
9.7	Abrasion test of cable assembly.....	31
9.7.1	Object.....	31
9.7.2	Procedure.....	31
9.8	Vibrations, shocks.....	31
9.9	Impact test.....	31
9.10	Mechanical endurance	31
10	Environmental tests	32
10.1	Recommended severities	32
10.2	Vibration, bumps and shock	32
10.3	Climatic sequence.....	32
10.3.1	Procedure.....	32
10.3.2	Requirements	32
10.3.3	Information to be given in the detail specification	32
10.4	Damp heat, steady state	32
10.4.1	Procedure.....	32
10.4.2	Requirements	32
10.4.3	Information to be given in the detail specification	33
10.5	Rapid change of temperature	33
10.5.1	Procedure.....	33
10.5.2	Requirements	33
10.5.3	Information to be given in the detail specification	33
10.6	Resistance to solvents and contaminating fluids	33
10.6.1	Procedure.....	33
10.6.2	Requirements	33
10.6.3	Information to be given in the detail specification	34
10.7	Water immersion.....	34
10.7.1	Procedure.....	34
10.7.2	Requirements	34

10.7.3	Information to be given in the detail specification	34
10.8	Salt mist and sulphur dioxide tests	34
10.8.1	Procedure	34
10.8.2	Requirements	34
10.8.3	Information to be given in the detail specification	34
10.9	Dust tests	34
10.9.1	Object	34
10.9.2	Procedure	35
10.9.3	Requirements	35
10.9.4	Information to be given in the detail specification	35
10.10	Flammability	36
10.10.1	Procedure	36
10.10.2	Requirements	36
10.10.3	Information to be given in the detail specification	37
11	Specialized test methods	37
12	Test schedules	37
Annex A (normative)	Test methods for insertion loss determination	38
A.1	Purpose	38
A.2	Test methods	38
A.2.1	General	38
A.2.2	Test method 1	38
A.2.3	Test method 2	39
A.2.4	Test method 3	41
A.3	Correction for characteristic impedance differences	42
Annex B (informative)	Measuring methods for propagation time	44
B.1	Introduction General	44
B.2	Resonance method for propagation time measurement	44
B.3	Time domain method for propagation time measurement	45
~~Annex C (informative)~~	~~Measurement method for screening effectiveness~~	~~46~~
~~C.1~~	~~Introduction~~	~~46~~
~~C.2~~	~~Test method~~	~~46~~
Annex C (informative)	Recommended severities for environmental tests	46
C.1	Introduction to the relationship between environmental conditions and severities of testing	49
C.1.1	General	49
C.1.2	Environmental conditions	49
C.1.3	Environmental testing	49
C.2	Recommended severities for environmental tests	50
C.2.1	Vibration	50
C.2.2	Bump	51
C.2.3	Shock	51
C.2.4	Climatic sequence	51
C.2.5	Damp heat, steady state	52
C.2.6	Rapid change of temperature	52
C.2.7	Salt mist	52
C.2.8	Sulphur dioxide test	52
C.2.9	Dust test	52
Annex D (normative)	Quality ~~assessment~~ management	53

D.1	~~Introduction~~ General	53
D.2	Object.....	53
D.3	~~General~~ Basic aspects	53
D.3.1	Related documents.....	53
D.3.2	Standards and preferred values.....	53
D.3.3	Marking of the cable assembly and packaging (see 5.2)	53
D.3.4	Terminology.....	54
D.4	Quality ~~assessment~~ management procedures	54
D.4.1	Procedures for qualification approval.....	54
D.4.2	Procedures for capability approval.....	55
D.4.3	Quality conformance inspection	56
D.5	Capability manual and approval	57
D.5.1	Responsibilities	57
D.5.2	Contents of the capability manual	57
D.5.3	Criteria for capability limits	58
	Bibliography.....	61
	~~Figure – Dust measuring device.....~~	
	Figure 1 – Bending test: U shape assembly	19
	Figure 2 – Bending test: straight assembly.....	20
	Figure 3 – Twisting test: U shape assembly	21
	Figure 4 – Fixture for cable assembly flexure test	27
	Figure 5 – Apparatus for cable assembly flexing endurance test	28
	Figure 6 – Fixture for cable crushing test	29
	Figure 7 – Example of test fixture for torque	30
	Figure 8 – Multiple bending test.....	31
	Figure A.1 – Circuit for the determination of insertion loss	38
	Figure A.2 – Circuit for the determination of insertion loss – principle	40
	Figure A.3 – Alternative circuit for the determination of insertion loss	40
	Figure A.4 – Double-pass circuit for the determination of insertion loss.....	41
	Figure B.1 – Arrangement of test equipment	44
	Figure C.1 – Description of action needed for the preparation of the environmental test specification.....	50
	Table 1 – Standard range of atmospheric conditions	14
	Table C.1 – Relationship between displacement and acceleration.....	51
	Table C.2 – Relationship between peak acceleration and velocity change.....	51
	Table D.1 – Example of capability limits for cable assemblies	59
	Table D.2 – Example of capability limits for flexible cables.....	59
	Table D.3 – Example of capability limits for connectors.....	59
	Table D.4 – Example of flow chart (see D.5.2.5)	60

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIO FREQUENCY AND COAXIAL CABLE ASSEMBLIES –

Part 1: Generic specification – General requirements and test methods

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60966-1 has been prepared by technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories.

This third edition cancels and replaces the second edition published in 1999. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Annex C (informative) Measurement method for screening effectiveness was cancelled;
- b) Subclause 8.9 gives references to relevant test procedures.

The text of this standard is based on the following documents:

FDIS	Report on voting
46/700A/FDIS	46/704/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60966 series, published under the general title *Radio frequency and coaxial cable assemblies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

RADIO FREQUENCY AND COAXIAL CABLE ASSEMBLIES –

Part 1: Generic specification – General requirements and test methods

1 Scope

This part of IEC 60966 specifies requirements for radio frequency coaxial cable assemblies operating in the transverse electromagnetic mode (TEM) and establishes general requirements for testing the electrical, mechanical and environmental properties of radio frequency coaxial cable assemblies composed of cables and connectors. Additional requirements relating to specific families of cable assemblies are given in the relevant sectional specifications.

NOTE The design of the cables and connectors used ~~should~~ will preferably conform to the applicable parts of IEC 61196 and IEC 61169 respectively.

NOTE 1 This document does not include tests which are normally performed on the cables and connectors separately. These tests are described in IEC 61196-1 (all parts) and IEC 61169-1 respectively.

NOTE 2 Wherever possible, cables and connectors used in cable assemblies, even if they are not described in the IEC 61196 or IEC 61169 series, are tested separately according to the tests given in the relevant generic specification.

NOTE 3 Where additional protection is applied to a cable assembly, the mechanical and environmental tests described in this document are applicable.

2 Normative references

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 60068 (all parts), *Environmental testing*

~~IEC 60068-2-3:1969, Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state~~

IEC 60068-2-6:1995, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-11:1981, *Basic environmental testing procedures – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-14:1984, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-27:1987, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

~~IEC 60068-2-29:1987, Environmental testing – Part 2: Tests – Test Eb and guidance: Bump~~

IEC 60068-2-42:1982, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60068-2-68:1994, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

~~IEC 60096-1:1986, Radio frequency cables – Part 1: General requirements and measuring methods~~

~~IEC 60332-1:1993, Tests on electric cables under fire conditions – Part 1: Test on a single vertical insulated wire or cable~~

IEC 60332-1-2:2004, *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*

~~IEC 60339 (all parts), General purpose rigid coaxial transmission lines and their associated flange connectors~~

~~IEC 60512-5:1992, Electromechanical components for electronic equipment, basic testing procedures and measuring methods – Part 5: Impact tests (free components), static load tests (fixed components), endurance tests and overload tests~~

IEC 60512-6-2, *Connectors for electronic equipment – Tests and measurements – Part 6-2: Dynamic stress tests – Test 6b: Bump*

IEC 60512-7-2, *Connectors for electronic equipment – Tests and measurements – Part 7-2: Impact tests (free components) – Test 7b: Mechanical strength impact*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60966-2 (all parts), *Radio frequency and coaxial cable assemblies*

IEC 60966-3 (all parts), *Radio frequency and coaxial cable assemblies*

IEC 60966-4 (all parts), *Radio frequency and coaxial cable assemblies*

IEC 61169 (all parts), *Radio-frequency connectors*

IEC 61169-1:1992 2013, *Radio-frequency connectors – Part 1: Generic specification – General requirements and measuring methods*

IEC 61196 (all parts), *Coaxial communication cables*

~~IEC 61196-1:1995, Radio frequency cables – Part 1: Generic specification – General definitions, requirements and test methods~~

IEC 61196-1-119, *Coaxial communication cables – Part 1-119: Electrical test methods – RF power rating*

~~IEC 61726:1995, Cable assemblies, cables, connectors and passive microwave components – Screening attenuation measurement by the reverberation chamber method~~

IEC 62037-2, *Passive RF and microwave devices, intermodulation level measurement – Part 2: Measurement of passive intermodulation in coaxial cable assemblies*

IEC 62153-4-6, *Metallic cables and other passive components test methods – Part 4-6: Electromagnetic compatibility (EMC) – Surface transfer impedance – Line injection method*

IEC 62153-4-7:2015, *Metallic communication cable test methods – Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring of transfer impedance Z_T and screening attenuation a_s or coupling attenuation a_C of connectors and assemblies up to and above 3 GHz – Triaxial tube in tube method*

~~IEC QC 001002:1986, Rules of procedure of the IEC quality assessment system for electronic components (IECQ)~~

~~ISO 9000, Quality management and quality assurance standards~~

~~ISO 9001:1994, Quality systems – Model for quality assurance in design, development, production, installation and servicing~~

~~ISO 9002:1994, Quality systems – Model for quality assurance in production, installation and servicing~~

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

cable assembly

combination of cable(s) and connector(s) with or without any additional protection and with specified performance, used as a single unit

3.2

flexible cable assembly

cable assembly where the cable is capable of repeated flexure

Note 1 to entry: The cable usually has a braid outer conductor.

3.3

semi-flexible cable assembly

cable assembly not intended for applications requiring repeated flexure of the cable in service, but bending or forming is permissible to facilitate installation

3.4

semi-rigid cable assembly

cable assembly not intended to be bent or flexed after manufacture

Note 1 to entry: Any bending or flexing during installation or use may degrade the performance of the cable assembly.

3.5

insertion loss

loss introduced by inserting a cable assembly into a system

Note 1 to entry: In this standard, it is the ratio, expressed in decibels, of the power (P_1) delivered to a load connected directly to a source and the power (P_2) delivered to a load when the cable assembly is inserted between the source and the load.

$$\text{Insertion loss} = 10 \times \log \left(\frac{P_1}{P_2} \right)$$

3.6

reflection factor

ratio of the complex wave amplitude of the reflected wave to the complex wave amplitude of the incident wave at a port or transverse cross-section of a transmission line

3.7

electrical length

equivalent free-space length of the cable assembly

3.8

electrical length difference

difference in electrical length between cable assemblies

3.9

phase difference

difference in phase between a transverse electromagnetic mode (TEM) wave which has traversed the cable assembly and an identical wave which has traversed another cable assembly

3.10

propagation time

time taken for the propagation of a TEM wave between the reference planes of the two connectors

3.11

minimum static bending radius

radius used in climatic tests

Note 1 to entry: It is the minimum permissible radius for fixed installation of the cable.

3.12

dynamic bending radius

~~the bending~~ radius ~~is~~ used for the insertion loss stability, stability of electrical length and flexing endurance tests

Note 1 to entry: It is the minimum bending radius for applications where the cable assembly is flexed. Larger bending radii will allow the increase of the maximum number of flexures.

~~3.10 screening effectiveness~~

3.13

transfer impedance

quotient of the induced voltage on the inside of the cable assembly and the inducing current outside the assembly

Note 1 to entry: In practice, this is between defined points on connectors mated to the connectors of the cable assembly

3.14

screening attenuation

ratio of the signal power inside the cable assembly to the total power that radiates outside the cable assembly

3.15

power rating

input power which may be handled continuously by the cable assembly when terminated by its characteristic impedance

Note 1 to entry: For practical application, the maximum power that may be handled is dependent upon the return loss.

Note 2 to entry: Power rating is dependent on mounting details, ambient temperature, air pressure and circulation. It is normally specified at an ambient temperature of 40 °C.

3.16

artificial ageing

process used to improve the stability of phase attenuation and expansion with temperature

Note 1 to entry: This process normally consists of submitting the complete cable assembly to a number of temperature cycles. Unless otherwise specified in the relevant detail specification, submitting the complete cable assembly to artificial ageing is optional, at the discretion of the supplier.

4 Design and manufacturing requirements

4.1 Cable design and construction

Cables in accordance with, or conforming to, IEC 61196 sectional or detail specifications ~~shall~~ should be specified wherever possible. Where cable designs deviating from IEC 61196 sectional or detail specifications are required, these cables shall comply with the requirements of the relevant sectional or detail specification of the manufacturer.

According to local regulation, raw material of the cable as well as those of additional protection shall be chosen to comply with regional or national Directives and Regulations such as RoHS and REACH in Europe.

4.2 Connector design and construction

Connector types conforming to the relevant part of IEC 61169 shall be specified wherever possible, but where a special connector design is required, the interface shall conform to the relevant part of IEC 61169, where available, and the connector construction shall comply with the requirements of the relevant detail specification.

According to local regulation, raw material of the connector as well as those of additional protection shall be chosen to comply with RoHS and other environmental regulation such as REACH in Europe.

4.3 Outline and interface dimensions

Outline dimensions shall be in accordance with the relevant detail specification of the cable assembly.

Interface dimensions shall be in accordance with the relevant detail specification.

5 Workmanship, marking and packaging

5.1 Workmanship

There shall be no observable defects in the cable assembly. It shall be clean and in good condition.

5.2 Marking

Marking shall be legible and in accordance with the relevant detail specification. It shall identify the manufacturer of the cable assembly.

5.3 End caps

Unless otherwise specified in the relevant detail specification, disposable end caps of suitable material for transport and storage shall be fitted to the connectors to protect at least each interface from damage and dirt.

5.4 Packaging and labelling

Packaging and labelling shall be in accordance with the relevant detail specification, unless otherwise specified.

6 Quality ~~assessment~~ management

A guide for quality ~~assurance~~ management including capability approval as well as qualification approval is given in Annex D.

7 Test methods – General

7.1 Standard atmospheric conditions for testing

~~Unless otherwise specified, all tests shall be carried out under the conditions specified in IEC 60068.~~

~~Before the measurements are made, the cable assemblies shall be stored at the measuring temperature for a time sufficient to allow the entire cable assembly to reach this temperature. When measurements are made at a temperature other than the standard temperature, the result shall, where necessary, be corrected to the standard temperature.~~

Standard atmospheric conditions need to be controlled within some range to ensure proper correlation of data obtained from measurements and test conducted in various facilities. Conduct measurement and test conditions under the following atmospheric conditions, unless otherwise specified. In some cases, special ambient conditions may be needed and be specified in the detail specification.

Table 1 gives the standard range of atmospheric conditions for carrying out measurements and tests.

Table 1 – Standard range of atmospheric conditions

Conditions	Standard
Temperature	23 °C ± 5 °C
Relative humidity	(45 ± 25) %
Atmospheric pressure (Limits are inclusive)	Site ambient

Keep variations in ambient temperature and humidity to a minimum during a series of measurements.

NOTE Where it is impracticable to carry out tests under the standard atmospheric conditions for testing, a note to this effect, stating the actual conditions of tests, ~~should~~ shall be added to the test report.

7.2 Visual inspection

The specimen shall be visually examined to ensure that:

- a) the condition, workmanship and finish are satisfactory;
- b) the marking is in accordance with 5.2 of this document;
- c) there is no mechanical damage, undesired movement or displacement of parts;
- d) no pitting or flaking of materials or finishes is apparent.

Examination may generally be carried out using an instrument with up to three times magnification.

7.3 Dimensions inspection

7.3.1 Interface dimensions

The interface dimensions shall be tested for compliance with the relevant detail specification with the appropriate test equipment.

Where connectors conforming to IEC 61169 [sectional and detail specifications](#) are used, inspection of interface dimensions may be limited to those features likely to vary as a result of incorrect assembly, for example the axial dimensions from reference plane to dielectric, and to inner contact features.

Where other connectors are used or where special requirements exist, details shall be given in the relevant detail specification.

7.3.2 Outline dimensions

Outline dimensions shall be measured according to the sketches of IEC 60966-2 (all parts), IEC 60966-3 (all parts) or IEC 60966-4 (all parts) as relevant.

Any special requirements for the measurement of cable assembly outline dimensions shall be given in the relevant detail specification.

8 Electrical tests

8.1 Reflection properties

8.1.1 Object

To determine the amount of signal that is reflected back to the signal source by the cable assembly under test in a matched system. The reflection behaviour is preferably expressed in terms of 'dB return loss'.

8.1.2 Test equipment

A vector network analyzer (VNA) capable of performing s-parameter measurements using calibration standards (open, short, load) that enables the RF performance of radio frequency (RF) and microwave devices to be characterized in terms of network scattering parameters or S parameters.

The return loss of the cords under test shall be measured with the VNA over the specified range of interest.

A detailed description of the error correction (calibration) procedure is given in the manual of the VNA.

Precision test adaptors (or test leads) with small inherent reflections shall be fitted on both ends of the cord under test to allow direct connection to the VNA and terminating load.

8.1.3 Procedure

~~The return loss of a cable assembly should be measured with a suitable network analyser.~~

For the measurement of the reflection characteristics of cable assemblies, special care ~~must~~ shall be given to the following:

- ensure that the sweep speed is slow enough for the reflected signal to remain in the centre of the IF-filter of the receiver system. The longer the cable, the slower the sweep speed that ~~must~~ shall be chosen;
- cable assemblies might have narrow return loss spikes. For continuous network analyser-systems, the sweep rate shall be low enough and for digital network analyser-systems, the number of measurement points shall be high enough for resolving eventual return loss spikes.

For example, for digital systems, the number of points should be:

$$n \geq 3(f_2 - f_1) L / (120)$$

where

n is the number of sampling points in the frequency range f_1 to f_2 forming the response curve;

f_1 is the lowest frequency in the range, in MHz;

f_2 is the highest frequency in the range, in MHz;

L is the physical length of the test specimen, in m.

Failing to apply these criteria may result in too wide a distance between the frequency sampling points, thus leading to considerable measuring failures.

The return loss of cable assemblies is not necessarily symmetrical for both sides, and measurements from both sides might be required. Unless otherwise stated in the relevant detail specification, the worst case has to be within the specification.

The system has to be calibrated with the appropriate connector types. If these are not available, then adapters have to be used. The adapters will give a deterioration in the measured return loss, but, the result shall not be corrected for the adapters. The combined return loss, including the adapters, shall be within the specification.

Other techniques for measuring the reflection characteristics of a cable assembly may be used if agreed by the customer.

8.1.4 Requirements

The measured return loss values shall be within the specified limits.

8.1.5 Information to be given in the detail specification

- minimum return loss, as a function of frequency, if appropriate;
- frequency range;
- required frequency resolution.

Measurements to be made from one or both ends.

8.2 Uniformity of impedance

8.2.1 Object

To determine the variation of local characteristic impedance of the cable assembly.

8.2.2 Procedure

Measurement is made using a time domain reflectometer (TDR) with input step applied to the cable assembly through an air line acting as an impedance reference (see IEC 61196-1-112 and 61169-1:2013, 9.2.1.2.2). Impedance variation along the assembly shall be observed.

Alternatively, a system using frequency domain to time domain conversion may be used.

8.2.3 Requirements

To be as specified in the relevant detail specification.

8.2.4 Information to be given in the detail specification

- a) rise time of the TDR system;
- b) limits of impedance variation.

8.3 Insertion loss

8.3.1 Procedure

The insertion loss shall be inspected in accordance with Annex A.

8.3.2 Requirements

The insertion loss shall not exceed the specified limits at any frequency within the frequency band indicated in the relevant detail specification.

8.3.3 Information to be given in the detail specification

- a) maximum insertion loss, if appropriate, as a function of frequency;
- b) frequency range.

8.4 Insertion loss stability

8.4.1 Object

To determine the change of attenuation at a given frequency when the cable assembly is subjected to dynamic bending.

8.4.2 Procedure

During insertion loss measurement according to 8.3, the cable is wound on a mandrel of radius equal to the dynamic bending radius and using the number of turns indicated in the relevant detail specification.

8.4.3 Requirements

During and after the test, the specified change of insertion loss given in the relevant detail specification shall not be exceeded.

8.4.4 Information to be given in the detail specification

- a) dynamic bending radius of the cable (radius of the mandrel);
- b) number of turns and portion of the cable assembly on the mandrel;

- c) test frequencies.
- d) maximum change of insertion loss.

8.5 Propagation time

8.5.1 Procedure

The propagation time is inspected in accordance with Annex B.

8.5.2 Requirements

The propagation time shall not exceed the limits indicated in the relevant detail specification.

8.5.3 Information to be given in the detail specification

- a) frequency band in which the measurement is carried out (see Clause B.1) or rise time of the system (see Clause B.2);
- b) propagation time and tolerance.

8.6 Stability of electrical length

8.6.1 Object

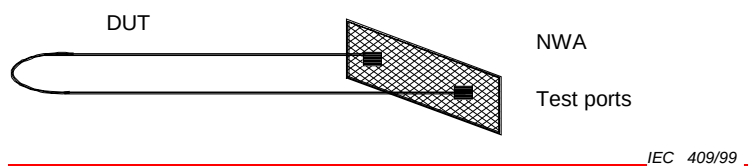
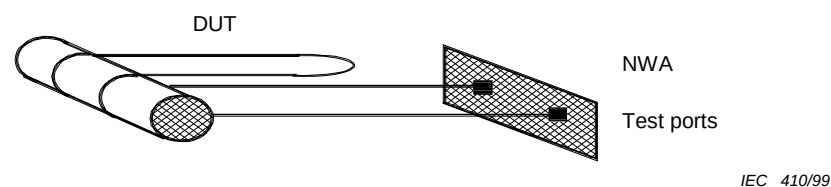
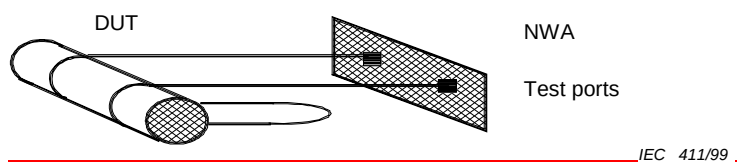
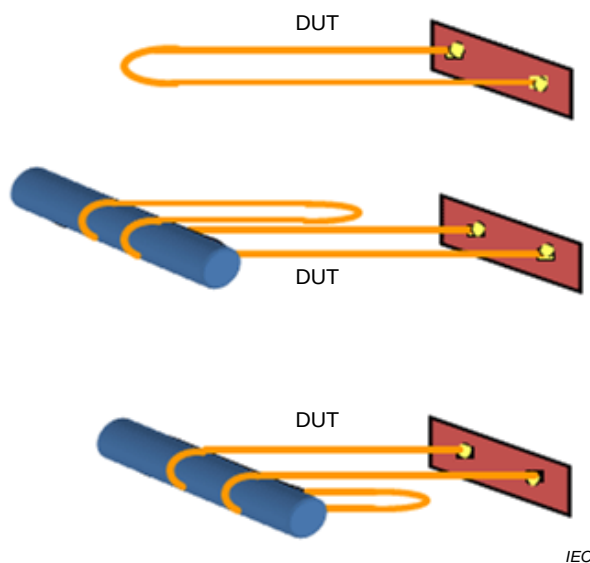
To determine the change of phase caused by the change in electrical length when the cable assembly is subjected either to bending or twisting.

8.6.2 Procedures

8.6.2.1 Bending

Method 1

A cable assembly which is of a U shape ~~has to~~ shall be connected to a suitable network analyser ~~(NWA)~~, according to 8.1.2 (see Figure 1). During recording of the phase of the transmitting signal, the cable is wound around the mandrel for 180° (see Figure 1), unwound to the starting position, wound counter-clockwise for 180° around the mandrel (see Figure 1) and again unwound to its starting position. The initial position of the mandrel shall be chosen so that only the straight parts of the U will be bent during the test.

**Figure 1a – Start position****Figure 1b – First bend****Figure 1c – Second bend****Figure 1 – Bending test: U shape assembly**

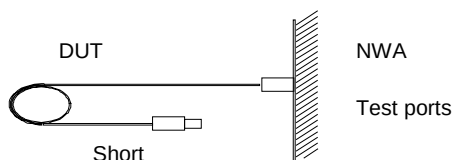
Method 2

A cable assembly which is of a straight shape has to be terminated by a short at one end and connected to a suitable network analyser according to 8.1.2 at the other end. During the recording of the phase of the reflected signal, the cable is first wound clockwise around the mandrel for one half turn released to the starting position then wound anti-clockwise around the mandrel and again released to its starting position. See Figure 2.



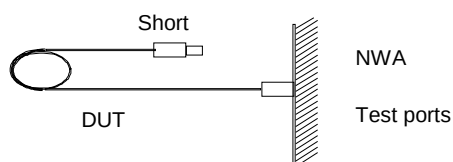
IEC 412/99

Figure 2a – Start position



IEC 413/99

Figure 2b – First bend



IEC 414/99

Figure 2c – Second bend

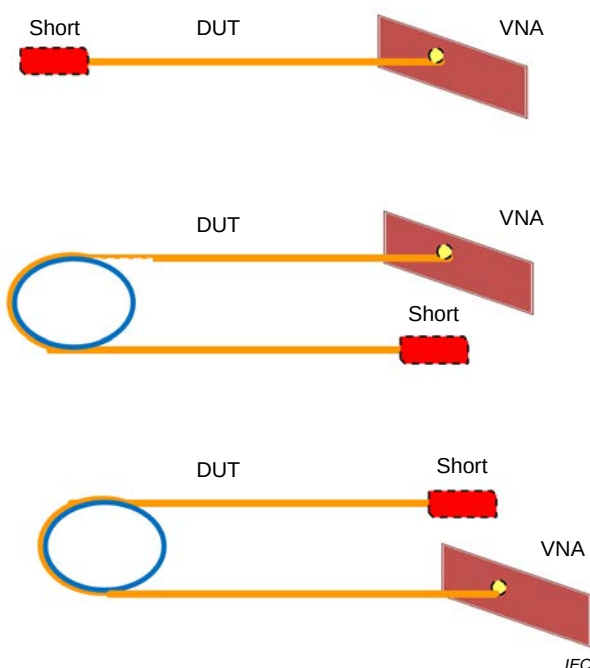


Figure 2 – Bending test: straight assembly

8.6.2.2 Twisting

A cable assembly which is of a U shape has to be connected to a suitable network analyser according to 8.1.2 (see Figure 3a). During the recording of the phase of the transmitting signal the mandrel in the middle of the cable is first twisted in a clockwise direction for 180° (see Figure 3b) then released to the starting position, twisted counter-clockwise for 180° (see Figure 3c) and again released to its starting position.

NOTE Depending on the torsional rigidity and the maximum permissible torque at the cable connectors interface, the maximum twist angle may have to be restricted.

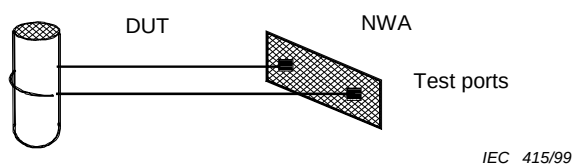


Figure 3a – Start position

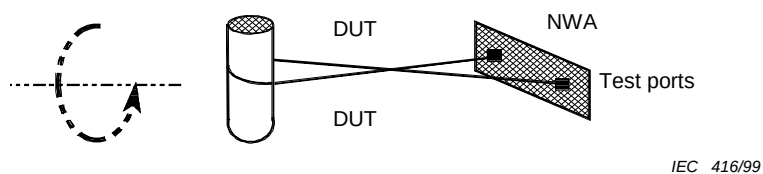
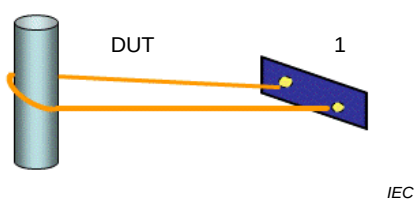
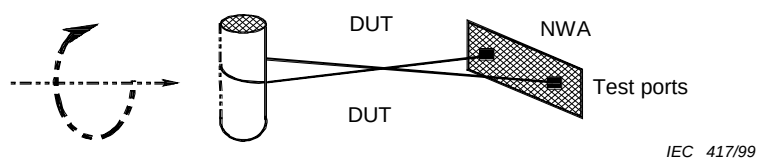
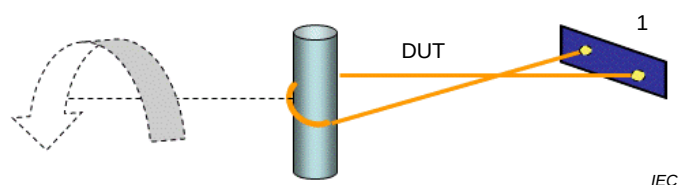


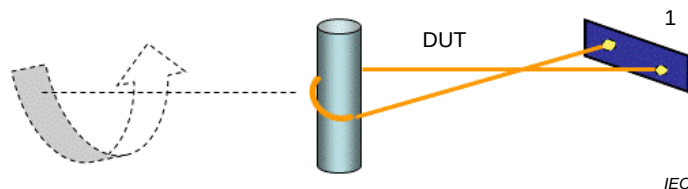
Figure 3b – First twist



a) Starting position



b) Clockwise twist



c) Counter clockwise twist

Figure 3 – Twisting test: U shape assembly

8.6.3 Requirements

The phase difference shall not exceed the limits specified in the relevant detail specification.

8.6.4 Information to be given in the detail specification

- a) radius of mandrel (usually dynamic bending radius of the cable);
- b) test frequency;
- c) maximum change of phase.

8.7 Phase difference

8.7.1 Object

To measure the phase difference between two or more cable assemblies.

8.7.2 Procedure

Measurements shall be made using a suitable network analyser of appropriate resolution according to 8.1.2. Alternatively, a slotted line may be used where frequency and accuracy requirements permit.

8.7.3 Requirements

The phase difference shall not exceed the limits specified in the relevant detail specification.

8.7.4 Information to be given in the detail specification

- a) maximum phase difference or nominal phase difference with tolerances;
- b) frequency.

8.8 Phase variation with temperature

8.8.1 Object

To determine the changes of phase caused by the change in the electrical length when the cable assembly is subjected to various temperatures within its operating temperature range.

When specified in the relevant detail specification, this test may be conducted on a specimen cable assembly rather than a finished cable assembly. The specimen cable assembly shall be identical to the finished cable assembly except for its length and its shape.

8.8.2 Procedure

Measurements shall be made using a suitable network analyser according to 8.1.2 with the cable assembly, including its connectors, in a controlled temperature chamber. Details of any cable supports shall be given in the relevant detail specification.

Where tests are made on a specimen cable assembly, the cable shall form one or more unsupported loops of a diameter at least ten or more times the minimum static bending radius.

Six temperature cycles shall be used. Alternatively, a slotted line can be used where frequency and accuracy requirements permit.

8.8.3 Requirements

During the test, the phase variation shall not exceed the limits specified in the relevant detail specification.

8.8.4 Information to be given in the detail specification

- a) temperature range and temperature against time cycle;
- b) measurement frequency;
- c) method of presenting the results, for example $\frac{\Delta\phi}{^\circ\text{C}}$;

- d) admissible phase variation;
- e) configuration of substitute specimen cable assembly, when allowed.

8.9 Screening effectiveness

8.9.1 Transfer impedance

The ~~screening effectiveness~~ transfer impedance shall be tested.

Applicable tests for transfer impedance are given in ~~annex C or in IEC 61726~~ IEC 62153-4-6 or IEC 62153-4-7.

The relevant detail specification shall identify the applicable test, the frequency range and the minimum value of ~~screening effectiveness~~ transfer impedance.

8.9.2 Screening attenuation

The screening attenuation shall be tested according to 62153-4-7.

The relevant detail specification shall identify the frequency range and the minimum value of screening attenuation.

8.10 Voltage proof

8.10.1 Procedure

Each cable assembly shall withstand, without breakdown or flashover, the voltage specified by the relevant detail specification. The minimum value of the test voltage derived from the rated working voltage U of the cable assembly and the test voltage E (both expressed as DC or AC peak) is given by:

$E = 3 U$ for cable assemblies having a rated working voltage up to and including 1 kV,

or

$E = 1,5 U$ with a minimum of 3 kV for cable assemblies having a rated working voltage exceeding 1 kV.

The peak AC voltage stated in the relevant detail specification, at a frequency between 40 Hz and 60 Hz, shall be applied between the inner and outer conductors of the cable assembly using a mated connector as an interface.

Alternatively, a DC voltage equal to the peak AC voltage may be applied.

The voltage shall be applied for a period of 1 min, unless otherwise stated in the relevant detail specification.

8.10.2 Requirements

There shall be no breakdown or flashover.

8.10.3 Information to be given in the detail specification

- a) test voltage;
- b) any special requirements.

8.11 Insulation resistance

8.11.1 Procedure

The insulation resistance shall be measured between the inner and outer conductor of the cable assembly with a direct voltage of $500\text{ V} \pm 50\text{ V}$ or with the rated voltage of the cable assembly, whichever is less.

The insulation resistance shall be measured after a stabilisation time of $60\text{ s} \pm 5\text{ s}$, unless otherwise specified in the relevant detail specification.

8.11.2 Requirements

The value of the insulation resistance shall not be less than that indicated in the detail specification.

8.11.3 Information to be given in the detail specification

- a) test voltage;
- b) stabilization time;
- c) resistance value.

8.12 Inner and outer conductor continuity

8.12.1 Object

To ensure the DC and low frequency continuity of the inner and outer conductors.

8.12.2 Procedure

Any appropriate method may be used.

8.12.3 Requirements

There shall be no undesired DC or low frequency discontinuity of the inner or outer conductor.

8.12.4 Information to be given in the detail specification

- a) test voltage;
- b) test current;
- c) frequency.

~~8.13 Void~~

8.13 Power rating

8.13.1 Object

The power rating of a cable assembly is defined as the input power at any specified frequency, temperature and pressure, which can be handled continuously when the cable assembly is terminated by a load corresponding to the characteristic impedance.

A limitation may be either the maximum permissible operating voltage or the maximum inner conductor temperature of either the cable or the connector.

Thus, the power handling capability test is divided into two categories:

- a) continuous power handling capability;
- b) peak or pulsed power handling capability.

8.13.2 Procedure

The test shall be performed in accordance with ~~11.19 of~~ IEC 61196-1-119 taking into account any evidence of arcing and mechanical displacement of the solder or mechanical joint.

8.13.3 Requirements

There shall be no evidence of breakdown due to overheating, arcing or flashover throughout the application of the specified power related to the environmental conditions as stated in the relevant detail specification. After the test, the cable assembly shall show no visual damage and the electrical requirements shall be satisfied.

The temperature rating of the material components should not be exceeded.

8.13.4 Information to be given in the detail specification

- a) temperature;
- b) pressure;
- c) relative humidity.

Peak power test

- d) power level;
- e) frequency;
- f) pulse width and duty cycle.

CW power test

- g) power level;
- h) frequency.

8.14 Intermodulation level measurement

~~Under consideration.~~

8.14.1 Procedure

If required, the intermodulation level measurement shall be performed in accordance with IEC 62037-2.

8.14.2 Requirements

The maximum intermodulation level shall be recorded and shall not exceed the given intermodulation level in the relevant detail specification.

8.14.3 Information to be given in the detail specification

- a) test signal power;
- b) test signal frequencies.

9 Mechanical robustness tests

9.1 Tensile

9.1.1 Object

To determine the mechanical strength and, when required, electrical stability of the cable assembly when subjected to an axial force.

9.1.2 Procedure

A tensile force as stated in the relevant detail specification shall be applied to the two connectors along the common axis of the cable and connectors. When the length or shape of the cable makes this impossible, the force shall be applied between the cable and each connector in turn.

NOTE When the force cannot be applied between the two connectors, these tests are normally destructive to the cable.

The application points of the force shall be given in the detail specification.

9.1.3 Requirements

There shall be no visual evidence of the movement of the cable relative to the connector.

Inner contact and insulator positions shall be in accordance with interface dimensions.

Electrical test requirements shall be complied with, if stated in the relevant detail specification.

9.1.4 Information to be given in the detail specification

- a) value of the force;
- b) duration and method of application of the force.
- c) Electrical tests required.

9.2 Flexure

9.2.1 Object

To determine the ability of the cable assembly to withstand bending at the junction of the cable and connector.

9.2.2 Procedure

The test shall be performed using a fixture as shown in Figure 4.

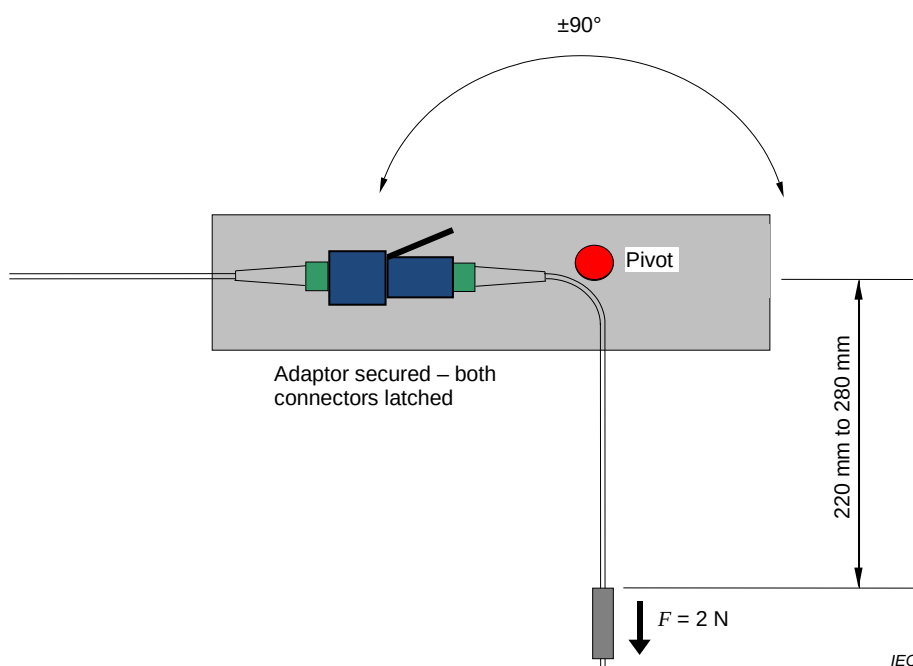


Figure 4 – Fixture for cable assembly flexure test

The length L is adjusted so that the cable is on the vertical axis and the connector in the horizontal position when the force F is applied. A flexure is a rotation of the fixture of 180° . The rate of flexure shall be 20 per minute or as stated in the relevant detail specification.

9.2.3 Requirements

After the test, the cable assembly interface dimensions shall be within the specified limits.

Electrical test requirements stated in the relevant detail specification shall be complied with.

9.2.4 Information to be given in the detail specification

- value of the force F ;
- number of flexures, normally 500;
- electrical tests required;
- whether or not electrical tests shall be applied with the cable assembly still on the fixture.

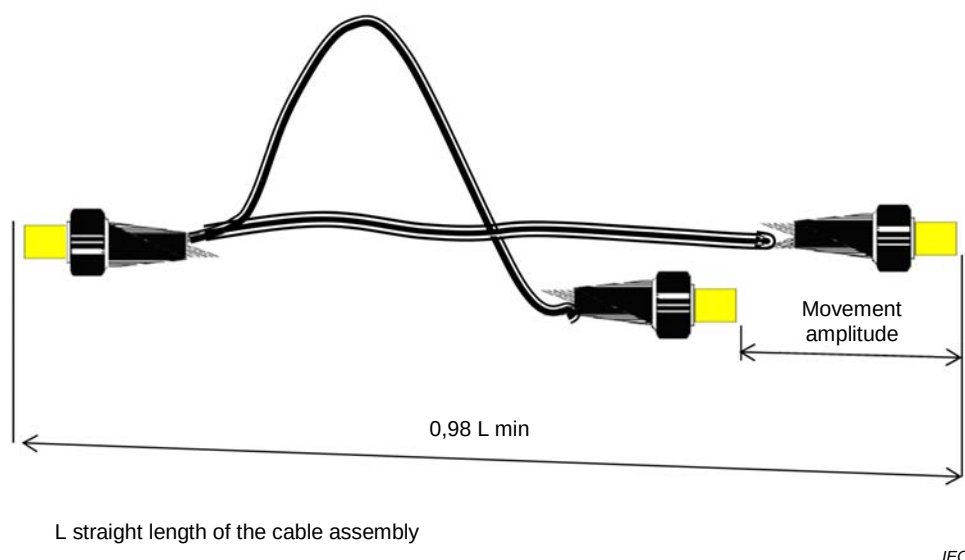
9.3 Flexing endurance

9.3.1 Object

To determine the acceptability of the cable assembly intended to withstand flexing in service.

9.3.2 Procedure

The cable assembly shall be placed on a horizontal table in an apparatus as illustrated in Figure 5. Whilst one connector is fixed, the other connector is moved back and forth in the direction of the cable axis.



Key

L min minimum length to be tested (in metres)

Figure 5 – Apparatus for cable assembly flexing endurance test

9.3.3 Requirements

After the test, the cable assembly shall show no visible damage and the interface dimensions shall be within the specified limits. Electrical requirements stated in the relevant detail specification shall be complied with.

9.3.4 Information to be given in the detail specification

- movement amplitude, normally half the length of the assembly;
- number of cycles, normally 500;
- electrical tests to be applied, with requirements.

9.4 Cable assembly crushing

9.4.1 Object

To determine the ability of a cable assembly to withstand a transverse load (or a force) applied to any part of the cable.

9.4.2 Procedure

A force F shall be applied to a test fixture as shown in Figure 6 at the rate of $0,2F$ per second maximum. The force shall then be maintained for $60\text{ s} \pm 10\text{ s}$.

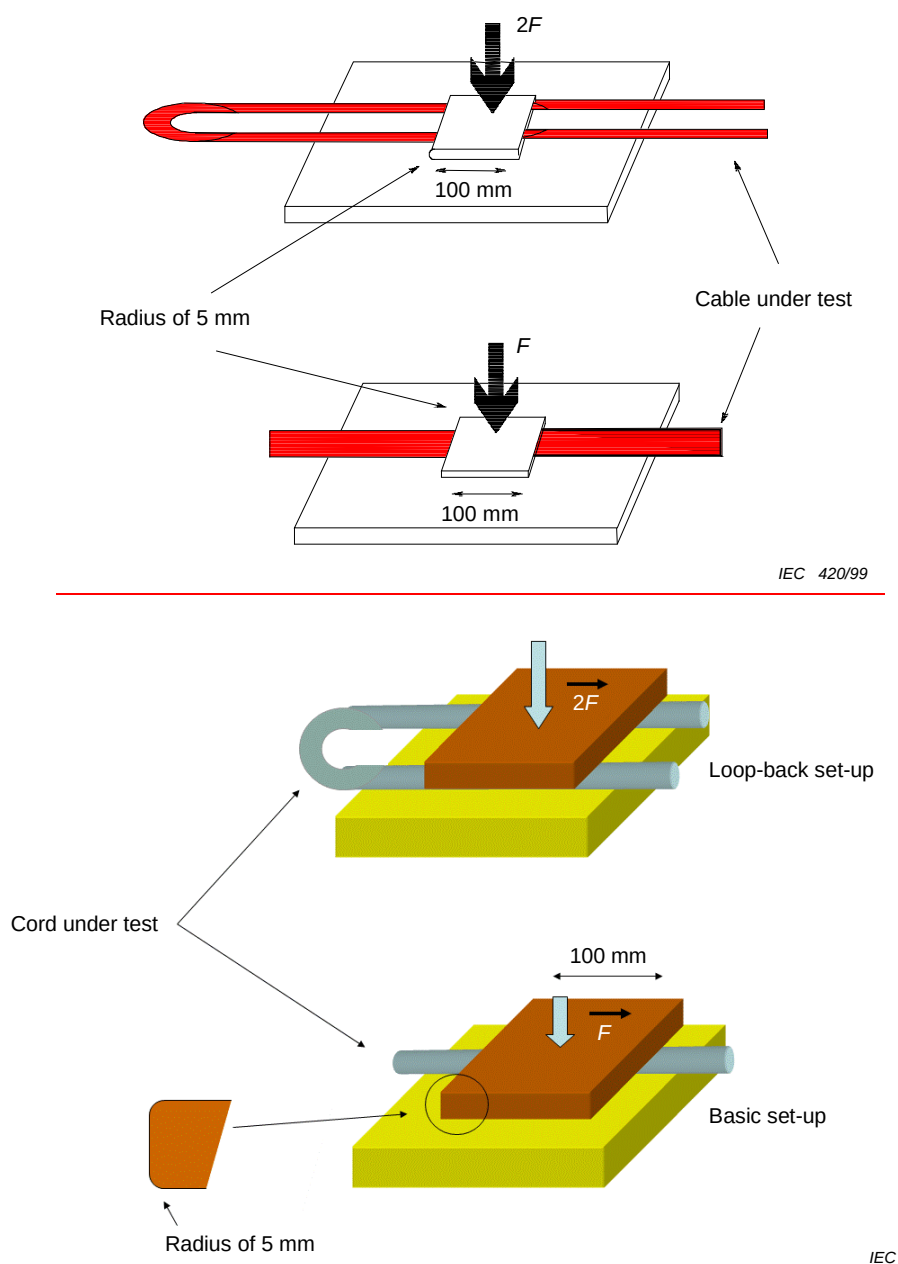


Figure 6 – Fixture for cable crushing test

9.4.3 Requirements

After the test, the reflection characteristics and insertion loss shall be within the limiting values specified in the relevant detail specification.

For some applications, the relevant detail specification shall indicate the uniformity of impedance according to 8.2.

9.4.4 Information to be given in the detail specification

- value of the force F , normally 800 N ;
- distance from the test region to one of the connectors, normally 1 m maximum;
- electrical tests and their requirements.

9.5 Torque

9.5.1 Procedure

The ability of the cable to resist torsion shall be tested by the application of a specific torque strictly axially to the interface of the cable to the connector. The torque shall be applied for at least 60 s in both clockwise and counter clockwise directions, see Figure 7.

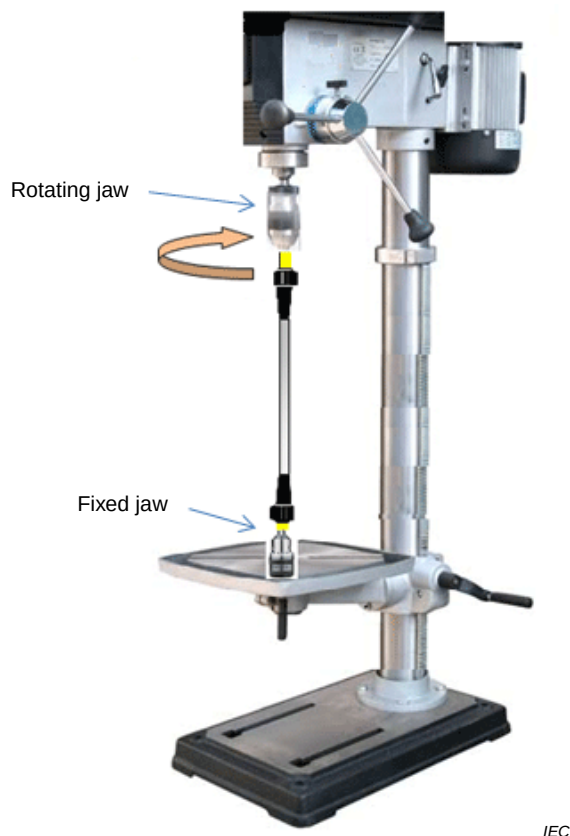


Figure 7 – Example of test fixture for torque

9.5.2 Requirements

After each 60 s application of the torque, the interface of the cable to the connector shall be visually examined. The cable assembly shall show no visual damage and the electrical requirements shall be satisfied. In addition, for semi-flexible and semi-rigid cables, there shall be no angular displacement between the cable and the connector.

9.5.3 Information to be given in the detail specification

Value of the torque.

9.6 Multiple bending

9.6.1 Object

To determine the ability of a cable assembly to withstand a number of reverse bends.

9.6.2 Procedure

The cable assembly is subjected to a certain number of reverse bends using a pulling "go and return" arrangement over its entire length. The radius of the two pulleys shall be in accordance with the minimum dynamic bending radius of the cable. The pulleys shall be

positioned so that the bending angle of the cable on each pulley is more than 90° as shown in Figure 8. The cable assembly is pulled forwards and backwards against a restraining force F_r which is set to ensure continuous contact between the cable and the pulleys.

9.6.3 Requirements

After the test, the cable assembly shall show no visual damage and the electrical requirements shall be satisfied.

9.6.4 Information to be given in the detail specification

- number of cycles (normally 20);
- electrical tests and their required limits to be applied.

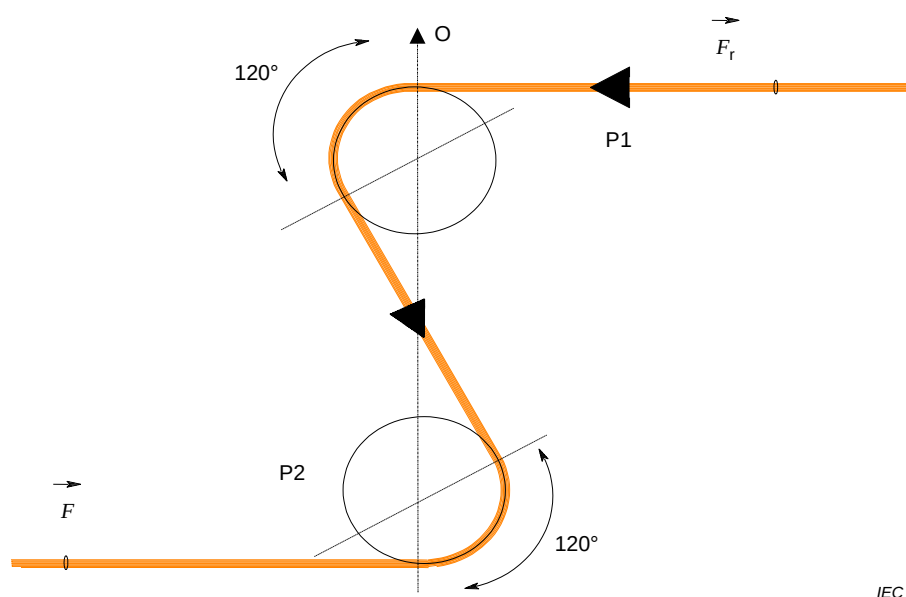


Figure 8 – Multiple bending test

9.7 Abrasion test of cable assembly

9.7.1 Object

To determine the resistance to abrasion of the cable assembly sheath.

9.7.2 Procedure

The cable assembly is subjected to test ~~10.10 of IEC 61196-1~~ given in IEC 61196-1-324.

9.8 Vibrations, shocks ~~and impact~~

If required, the test for vibrations and shocks shall be selected as defined in 10.2.

9.9 Impact test

This test shall be conducted in accordance with test 7b of ~~IEC 60512-5~~ IEC 60512-7-2.

9.10 Mechanical endurance

When this test is not performed on the connectors separately, it will be conducted in accordance with ~~9.5 of IEC 61169-1~~ IEC 61169-1:2013, 9.4.5 (High temperature endurance) and, 9.4.6 (Low temperature endurance).

10 Environmental tests

10.1 Recommended severities

For the recommended severities of environmental tests, see Annex C.

Recommended set of severities may also be found in ISO/IEC TR 29106.

10.2 Vibration, bumps and shock

When these tests are required, they shall be selected from IEC 60068 (all parts) (see Annex C).

10.3 Climatic sequence

10.3.1 Procedure

The test shall be performed in accordance with 9.4.2 of IEC 61169-1:2013.

Flexible cable assemblies shall be wound on a mandrel of minimum static bending radius. The number of full turns shall be three, unless otherwise stated in the relevant detail specification.

10.3.2 Requirements

At the conclusion of the recovery period, the cable assembly shall comply with the requirements of the following tests, unless otherwise stated in the relevant detail specification.

- a) insulation resistance;
- b) voltage proof;
- c) insertion loss;
- d) visual inspection.

The insulation resistance measurement and the voltage proof shall be carried out within 30 min of the end of the recovery period.

10.3.3 Information to be given in the detail specification

- a) severity of each step of the climatic sequence;
- b) number of turns on the mandrel if other than three;
- c) electrical tests made during and after the sequence and their requirements;
- d) whether connectors are unmated or protected.

10.4 Damp heat, steady state

10.4.1 Procedure

The flexible cable assembly shall be wound on a mandrel of minimum static bending radius. The number of full turns shall be three, unless otherwise stated in the relevant detail specification. The test shall be performed in accordance with 9.4.3 of IEC 61169-1:2013.

10.4.2 Requirements

At the conclusion of the recovery period, the cable assembly shall comply with the requirements of the following tests, unless otherwise stated in the relevant detail specification.

- a) insulation resistance;

- b) voltage proof;
- c) insertion loss;
- d) visual inspection.

The insulation resistance and the voltage proof measurements shall be carried out within 30 min of the end of the recovery period.

10.4.3 Information to be given in the detail specification

- a) severity of the test;
- b) number of turns on the mandrel if other than three;
- c) electrical checks made immediately after conditioning and after recovery period and their requirements;
- d) whether connectors are mated or unmated.

10.5 Rapid change of temperature

10.5.1 Procedure

The test shall be performed in accordance with 9.4.4 of IEC 61169-1:2013. Flexible cable assemblies shall be wound on a mandrel of minimum static bending radius. The number of full turns shall be three, unless otherwise stated in the relevant detail specification.

The coil turns should be spaced to avoid contact with each other.

10.5.2 Requirements

At the conclusion of the recovery period, the cable assembly shall comply with the requirements of the following tests, unless otherwise stated in the relevant detail specification.

- a) insulation resistance;
- b) voltage proof;
- ~~c) Insertion loss.~~
- c) RL, IL, ZC, and electrical length;
- d) visual inspection.

Centre contact and insulator positions shall be in accordance with the interface dimensions.

10.5.3 Information to be given in the detail specification

- a) minimum and maximum temperature;
- b) number of turns on the mandrel if other than three;
- c) final tests and measurements and their requirements.

10.6 Resistance to solvents and contaminating fluids

10.6.1 Procedure

The test shall be performed in accordance with ~~9.7~~ 9.4.11 of IEC 61169-1:2013.

10.6.2 Requirements

At the conclusion of the recovery period, the cable assembly shall comply with the requirements of the following tests, unless otherwise stated in the relevant detail specification.

- a) Insulation resistance;

- b) Visual inspection;
- c) Insertion loss.

10.6.3 Information to be given in the detail specification

- a) conditioning fluids;
- b) drying temperature, if different from 70 °C;
- c) requirements for insulation resistance and insertion loss;
- d) whether the connectors are mated or unmated.

10.7 Water immersion

10.7.1 Procedure

Details of the method shall be given in the relevant detail specification and shall be generally in accordance with ~~9.2.7~~ 9.4.9 of IEC 61169-1:2013.

10.7.2 Requirements

At the conclusion of the test duration, the cable assembly shall comply with the requirements of the following tests, unless otherwise specified in the relevant detail specification.

- a) insulation resistance;
- b) insertion loss.

10.7.3 Information to be given in the detail specification

- a) requirements for insulation resistance and insertion loss;
- b) whether the connectors are mated or unmated.

10.8 Salt mist and sulphur dioxide tests

10.8.1 Procedure

When these tests are required, they shall be ~~selected from IEC 60068~~ performed according to 9.4.10 (salt) and 9.4.12 (sulphur) of IEC 61169-1:2013. Severities are to be given in the relevant detail specification.

10.8.2 Requirements

At the conclusion of the recovery period, the cable assembly shall comply with the requirements of the following tests, unless otherwise stated in the relevant detail specification:

- a) insulation resistance;
- b) visual inspection;
- c) insertion loss.

10.8.3 Information to be given in the detail specification

- a) requirements for insulation resistance and insertion loss;
- b) whether the connectors are mated or unmated.

10.9 Dust tests

10.9.1 Object

To determine whether the effects of exposure to dust impair the operational performance of the cable assembly and in particular the function of the coupling mechanism.

10.9.2 Procedure

~~Details of a typical test cabinet for carrying out this test are given in 10.9.5. The dust medium shall be fine powdered silica as detailed in 10.9.5.~~

~~The dry specimen(s) with connectors mated and with back-of-panel portion of fixed connectors and free ends of cable protected, when appropriate, against ingress of dust shall be placed in the cabinet simulating the normal operational altitude. (If the normal operational altitude is indefinite, the specimen(s) shall be positioned in the altitude most likely to prove adverse).~~

~~No relevant part of any specimen shall be closer than 150 mm to the sides, top or bottom of the cabinet or part of another specimen during the test.~~

~~Each test cycle shall be of 15 min duration, during which the air blast shall be operated for the first 2 s only.~~

~~The number of test cycles to which the specimens will be exposed will be dependent upon the severity of exposure to dust likely to be met in service. The following are the preferred test severities:~~

- ~~a) Severe dust conditions: — 20 cycles.~~
- ~~b) Moderate dust conditions: — 10 cycles.~~
- ~~c) Slight dust conditions: — 2 cycles.~~

The cord will be submitted to the test defined by IEC 60529 for a classification IP 5X.

The details of the test (mated or unmated connector(s)) shall be given in the detail specification.

10.9.3 Requirements

At the conclusion of the last cycle, the specimen(s) shall be carefully removed from the chamber and any surplus dust removed by a light shaking or blowing. Before uncoupling the connector, any measurements required by the detail specification to check for deterioration in performance shall be made.

10.9.4 Information to be given in the detail specification

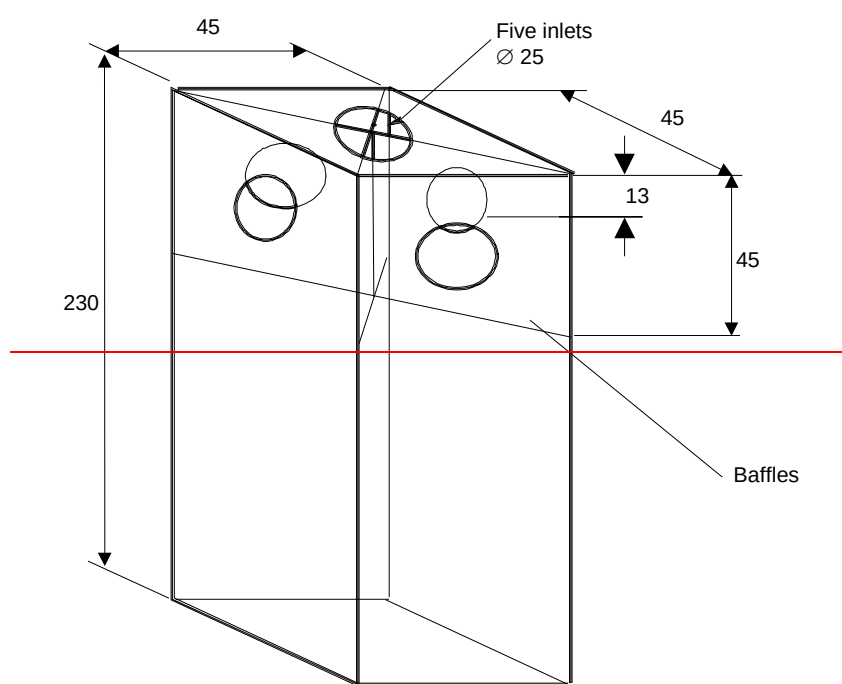
- a) duration of test cycle if other than 15 min;
- b) the equivalent altitude if other than that covered by the standard atmospheric conditions for testing;
- c) number of test cycles;
- d) details of visual, mechanical and electric inspection and tests required at the conclusion of the conditioning including whether a special tool may be used to assist uncoupling of mated connector;
- e) size of particles to be chosen from ~~6.1.4.2 of IEC 60068-2-68~~ IEC 60529.

10.9.5 Test chamber

~~The cabinet used shall be based on the typical details given below. The essential features are:~~

- ~~a) A dense diffusion of the dust shall be achieved within 2 s.~~
- ~~b) A glass observation panel incorporated in an opening door (with externally hand-operated wiper).~~

- ~~c) Means for holding the specimens in the cabinet in accordance with the requirements of this specification and the detail specification.~~
- ~~d) There shall be no increase in air pressure within the cabinet during the test and especially during the first 2 s of each cycle.~~
- ~~e) The test chamber temperature shall be capable of being raised to and maintained at a temperature of $35\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ with a relative humidity not exceeding 60 %. It shall be adjustable so as to produce a dust concentration sufficient to deposit $25\text{ g} \pm 5\text{ g}$ in the measuring device (see figure 8) over a period of 5 min.~~
- ~~f) Materials used for the construction of the cabinet shall be such that there shall be no contamination of the dust by foreign matter.~~
- ~~g) Details of the powdered medium to be as follows: dry silica with grains of $2,5\text{ }\mu\text{m}$ to $50\text{ }\mu\text{m}$ and grains of $50\text{ }\mu\text{m}$ to $150\text{ }\mu\text{m}$ (fifty/fifty).~~



IEC 422/99

Dimensions in millimetres

Figure 8 — Dust measuring device

10.10 Flammability

10.10.1 Procedure

The test shall normally be carried out in accordance with IEC 60332-1-2 on a finished cable assembly. Unless otherwise specified in the detail specification, the duration of flame application shall be derived from the formula given in ~~clause 7 of IEC 60332-1~~ 5.4.2 of IEC 60332-1-2:2004. In case of plastic components other than the cable itself, each one shall satisfy the requirements of the relevant specification.

10.10.2 Requirements

If ignition occurs, the cable shall not continue to burn for more than 15 s after removal from the flame.

At no time during the test shall burning particles become detached from the cable.

10.10.3 Information to be given in the detail specification

Any deviation from the standard procedure including regional or national regulations, if any.

11 Specialized test methods

Specialized test methods, applicable to a specific group of cable assemblies only, shall be specified in the relevant sectional specification.

12 Test schedules

Testing schedules shall be defined in sectional and relevant detail specifications.

NOTE Typical sub-families consist of RF cable assemblies manufactured from a specific type of cable, for example, flexible or semi-rigid, RF-connectors of an IEC standardized or proprietary design, and having specific characteristics, for example precision or super-screened.

Annex A (normative)

Test methods for insertion loss determination

A.1 Purpose

To determine the insertion loss of an RF cable assembly.

A.2 Test methods

A.2.1 General

Three test methods for the determination of the insertion loss of an RF cable assembly are described in this Annex A. The test equipment should have the same nominal characteristic impedance as the cable assembly under test. If this is not possible, test methods 1 and 2, given in A.2.2 and A.2.3, may only be used with the application of the correction formula and procedures given in Clause A.3.

Test method 3 is only suitable for RF cable assemblies having an insertion loss smaller than their return loss.

Adapters may be required between the test equipment and the cable assembly under test. These shall be regarded as part of the test equipment and shall be left in the circuit when the cable assembly is removed as part of the test procedure. However, should a cable assembly have connectors such that the adapters cannot be coupled together when the cable assembly is removed, one or more of the adapters may be left on the cable assembly. In this case, an allowance for the adapter(s) shall be made in the relevant detail specification.

A.2.2 Test method 1

A.2.2.1 Procedure for inspection

The cable assembly is tested in the test equipment circuit as shown in Figure A.1.

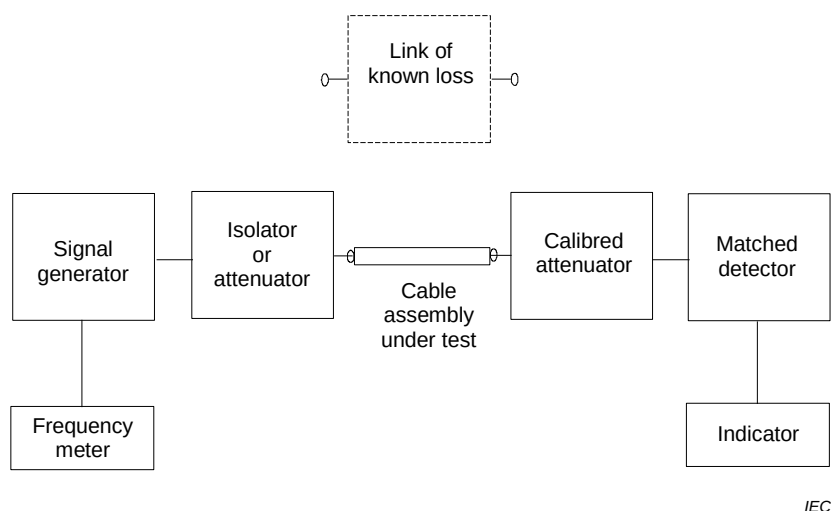


Figure A.1 – Circuit for the determination of insertion loss

First the cable assembly is either replaced by the link of known loss or the two test ports are coupled together and the indicator set to a suitable value (i.e. less than the maximum). The cable assembly is inserted between the test ports and the calibrated attenuator is then backed

off by an amount equal to the cable assembly limit, less the known loss of the link if used. The indicator reading shall not be less than the set value. This ensures that the insertion loss of the cable assembly is not more than the specified value.

A.2.2.2 Procedure for measurement

The cable assembly is tested in the test equipment circuit as shown in Figure A.1. The indicator is set to a suitable value (i.e. less than the maximum). The cable assembly is then removed and the indicator reading is returned to the set value using the calibrated attenuator and if necessary the link of known loss.

A.2.2.3 Acceptance

The insertion loss of the cable assembly shall be no greater than the specified value.

A.2.2.4 Precautions

- a) The return losses at the two test ports may impair measurement and shall be taken into account (see Clause A.3).
- b) Care shall be taken to ensure that too much power does not damage the detector.
- c) The oscillator shall be sufficiently pure or filtered, to ensure that neither harmonics nor spurious signals compromise the tests.
- d) See A.2.1 regarding the use of adapters.

A.2.3 Test method 2

A.2.3.1 General

This test method may be used for cable assemblies having the same nominal characteristic impedance as the test equipment (i.e. for high return loss cases) as well as for cable assemblies having different nominal characteristic impedances (i.e. for low return loss cases).

A.2.3.2 Procedure

The test circuit is shown in Figure A.2 whereby the detector V is connected to the output of the directional coupler or bridge through adapters as necessary.

Depending upon the test port return losses, calibration is made either by amplitude or by amplitude and phase (high return loss requires amplitude calibration only, while low return loss requires amplitude and phase calibration in accordance with Clause A.3). The cable assembly is inserted between the output of the directional coupler or bridge and the detector V, using adapters if necessary. The attenuation is determined on the swept amplitude analyser.

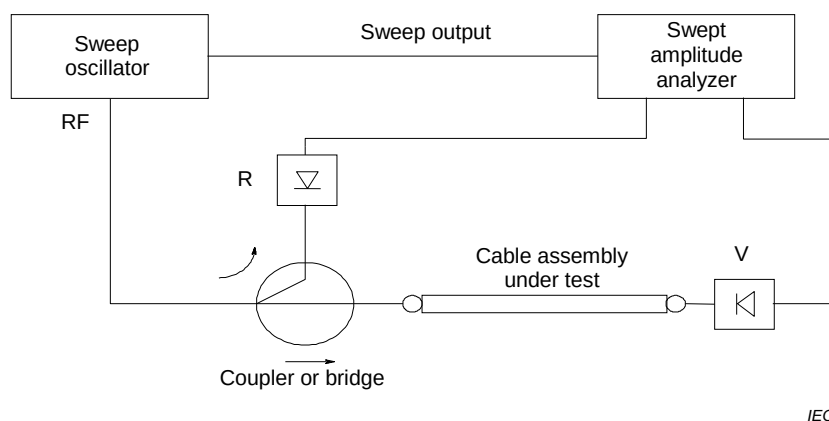


Figure A.2 – Circuit for the determination of insertion loss – principle

If sufficient power is available or if there is sufficient sensitivity in the systems, the alternative circuit shown in Figure A.3 may be used.

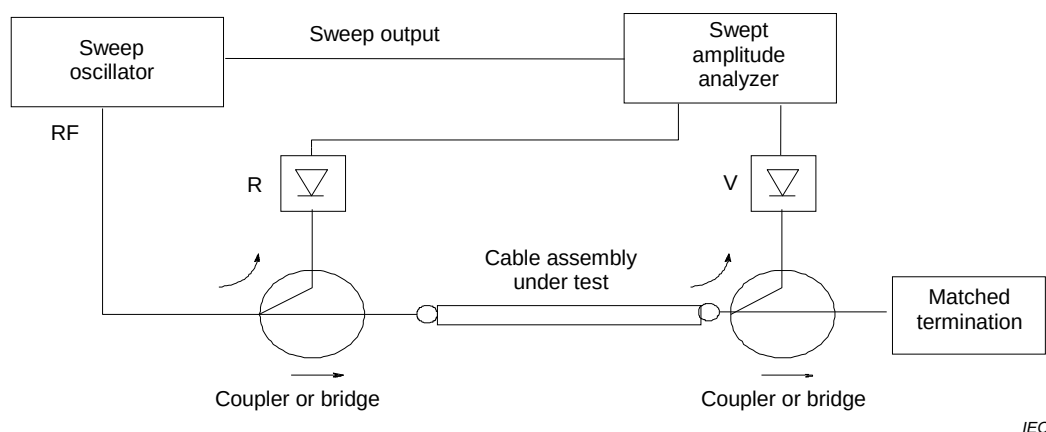


Figure A.3 – Alternative circuit for the determination of insertion loss

A.2.3.3 Acceptance

The insertion loss of the cable assembly shall be no greater than that specified.

A.2.3.4 Precautions

- The return losses at the two test ports may impair measurement and shall be taken into account (see Clause A.3). In particular, an attenuator having a low reflection may be required in front of the detector V.
- The calibration of the system shall take into account the power dependence of the coupler.
- The oscillator shall be sufficiently pure or filtered, to ensure that neither harmonics nor spurious signals compromise the tests.
- In analogue-swept systems, the frequency scan rate of the sweep oscillator shall be sufficiently slow in relation to the amplitude analyser response to obtain an accurate determination of the insertion loss. In particular, it shall be slow enough for cable assemblies in which there are:
 - resonances, which can be very sharp, associated with structural return loss in the cable assembly;
 - multiple reflections between the ends of the cable assembly or the test ports.

- e) In digitally stepped frequency systems, the steps shall be sufficiently fine for an accurate determination of the insertion loss. In particular, they shall be fine enough for the cases described in item d).
- f) See A.2.1 regarding the use of adapters.

A.2.4 Test method 3

A.2.4.1 General

A double-pass method of test may be used if the insertion loss of the cable assembly is smaller than its return loss and the test bandwidth is sufficient. This requirement precludes the testing of unmatched cable assemblies.

A.2.4.2 Procedure

The layout of the test circuit is shown in Figure A.4.

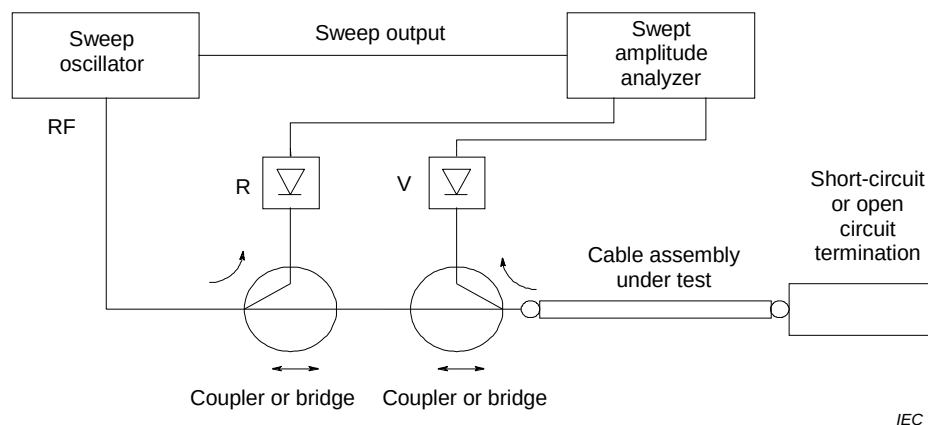


Figure A.4 – Double-pass circuit for the determination of insertion loss

Levels for V/R at 0 dB and for any other required attenuation are established over the required frequency range with terminations on the directional coupler port or adapters as follows:

- a) short-circuit;
- b) open-circuit.

The decibel average of these two levels a) and b) shall be deemed the reference level.

The cable assembly is then coupled to the directional coupler using adapters as necessary and attenuation levels are obtained with the short- and open-circuit terminations. The decibel average of the two plots obtained with the different terminations is twice the insertion loss of the cable assembly under test.

A.2.4.3 Acceptance

The insertion loss of the cable assembly shall be no greater than the specified value.

A.2.4.4 Precautions

- a) The return loss at the test port and the directivity of the directional coupler or the apparent directivity of the bridge impair the measurement and shall be taken into account (see Clause A.3).
- b) The test bandwidth shall be sufficient to provide confidence in averaging plots.
- c) The calibration of the system shall take into account the power dependence of the coupler.

- d) The oscillator shall be sufficiently pure or filtered, to ensure that neither harmonics nor spurious signals compromise the tests.
- e) In analogue-swept systems, the frequency scan rate of the sweep oscillator shall be sufficiently slow in relation to the amplitude analyzer response to obtain an accurate determination of the insertion loss. In particular, it shall be slow enough for cable assemblies in which there are:
 - 1) resonances, which can be very sharp, associated with structural return loss in the cable assembly;
 - 2) multiple reflections between the ends of the cable assembly or the test ports,
- f) In digitally stepped frequency systems, the steps shall be sufficiently fine for an accurate determination of the insertion loss. In particular they shall be fine enough for the cases described in item e).
- g) The insertion loss of the cable assembly shall permit resolution of the reflections from the cable assembly and its terminations.
- h) In open-circuit tests, radiation from the connector centre contacts shall not compromise accuracy. If necessary, precision open-circuit terminations (i.e. shielded or closed-end open-circuit terminations) shall be used.
- i) See A.2.1 regarding the use of adapters.

A.3 Correction for characteristic impedance differences

When the characteristic impedance of the test equipment and the cable assembly differ, test methods 1 and 2 may be used with the following correction formula:

$$A = A' - \left[20 \cdot \log \left(\frac{Z_g + Z_0}{2 \cdot \sqrt{Z_g \cdot Z_0}} \right) \right] - \left[20 \cdot \log \left(\frac{Z_1 + Z_0}{2 \cdot \sqrt{Z_g \cdot Z_1}} \right) \right] - \left[20 \cdot \log \left[1 - \left(\frac{Z_g - Z_0}{Z_g + Z_0} \cdot \frac{Z_1 - Z_0}{Z_1 + Z_0} \cdot e^{-2(\alpha + \beta)L} \right) \right] \right] \quad (\text{A.1})$$

where

- A is the true insertion loss of the cable assembly under test (dB);
- A' is the measured insertion loss of the cable assembly (dB);
- Z_g is the nominal output impedance of the generator's isolator/attenuator (test method 1) or the coupler or bridge (test method 2) (Ω);
- Z_0 is the nominal characteristic impedance of the cable assembly (Ω);
- Z_1 is the nominal input impedance of the calibrated attenuator (test method 1) or the detector or coupler/bridge (test method 2) (Ω);
- α is the attenuation constant of the cable assembly (neper/m);
- β is the phase constant of the cable assembly (radian/m);
- L is the physical length of the cable assembly (m).

When the attenuation against frequency shows a consistent ripple resulting from the multiple reflections between the two test ports, β may be obtained from:

$$\beta = \frac{\pi \cdot f}{\Delta f \cdot L} \quad (\text{A.2})$$

where

- Δf is the frequency difference between either two successive maxima or two successive minima in the attenuation ripple at approximately frequency f .

Further to this, α is approximately equal to α' which is obtained from:

$$\alpha = A'/8,686L \text{ neper/m} \quad (\text{A.3})$$

However, for greater accuracy, this formula may be used iteratively by substituting α for α' in the above equation.

Annex B (informative)

Measuring methods for propagation time

B.1 Introduction General

Methods for both long and short cable assemblies are needed. For long cable assemblies a method based on resonance of forward and backward waves is recommended. This resonance method is described in Clause B.2. For short cable assemblies the time domain method described in Clause B.3 is recommended.

B.2 Resonance method for propagation time measurement

The frequencies f_i of the voltage minima at the near end of a short-circuited cable assembly and/or the frequencies f_j of the voltage maxima of an open-circuited cable assembly are measured. The frequency of the first maximum or minimum is designated as f_1 , the second as f_2 , etc.

A suitable equipment arrangement is given in Figure B.1.

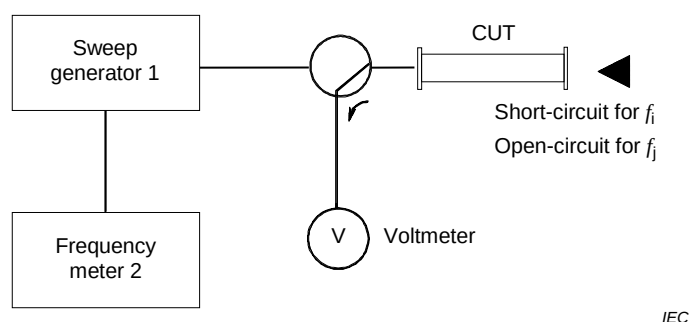


Figure B.1 – Arrangement of test equipment

The propagation time $T_{p,n}$ at frequency f_i or f_j is given by the formula:

$$T_{p,n} = \frac{n}{f_n}$$

where $n = i$ or j .

NOTE The electrical length of the coupling device and the adapter should be taken into account.

The accuracy can be improved by taking the mean values:

$$f_n = \frac{f_i + f_j}{2}$$

$$T_{pn} = \frac{T_{pi} + T_{pj}}{2}$$

where $n = i = j$.

For best accuracy, the cable shall be terminated with a short-circuited or open-circuited connector of the same electrical length.

At other than the above resonance frequencies, the following formula may be used. The coefficients are determined from measurement at several resonance frequencies f_n .

$$T_p = B_0 + B_{1f}^{-1/2} + B_{2f}^{-1/4} + \dots$$

B.3 Time domain method for propagation time measurement

For a short or very short cable assembly the propagation time can be determined by the time delay of an echo through the cable.

A time domain reflectometer (TDR) or a pulse echo test set can be used. The rise time of the system and the width of the pulse should be in accordance with the resolution needed.

The measured echo delay time should be divided by a factor of 2 to obtain the propagation time of the cable assembly. Allowance should be made for the electrical length of the short-circuit or open-circuit.

Annex C (informative)

Measurement method for screening effectiveness

C.1 Introduction

The screening effectiveness of a coaxial cable assembly is determined by the screening properties of its cable, its connectors and the joints between them. The transfer impedance may be measured by the line injection method depicted in figure C.1.

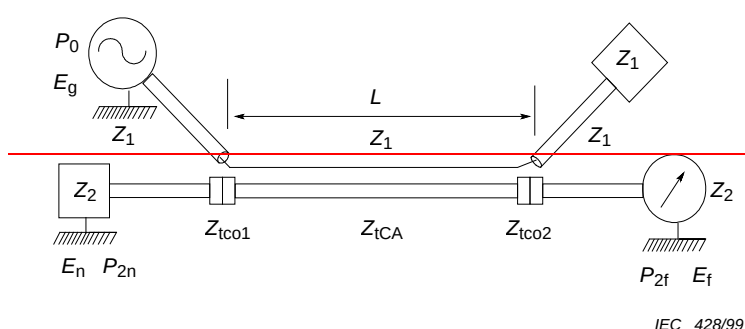


Figure C.1 — Line injection test circuit for coaxial cable assemblies

$$T_n = \sqrt{\frac{P_{2n}}{P_0}} \quad T_f = \sqrt{\frac{P_{2f}}{P_0}}$$

In these formulae, P_0 is the power input to the cable assembly; P_{2n} and P_{2f} are the measured powers from the near and far ends of the cable assembly, respectively.

When $Z_f = 0$, the measured coupling transfer functions are:

$$T_f = \left[\left(\frac{Z_{tCA}}{2 \times Z_{12}} \times S_J(f) \right) + \left(\frac{Z_{tco1} + Z_{tco2}}{2 \times Z_{12}} \right) \right]$$

where $Z_{12} = \sqrt{Z_1 \times Z_2}$

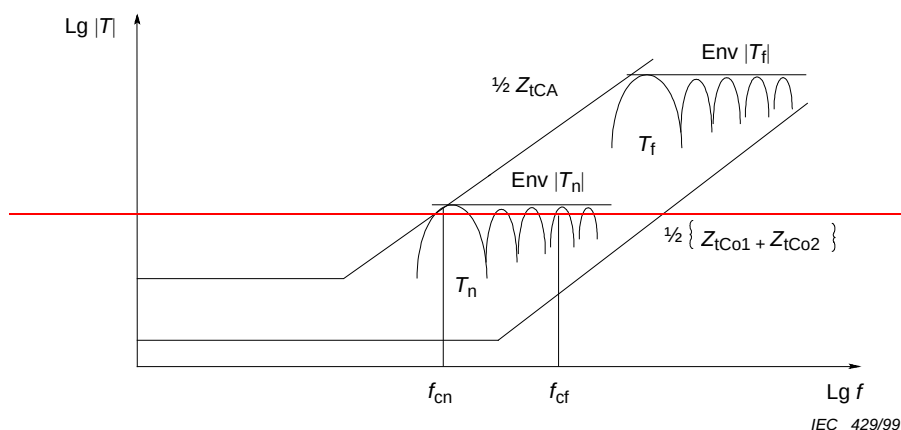


Figure C.2 — Schematic transfer functions of a coaxial cable assembly

~~In figure C.2, the cable is electrically long above frequency f_{cn} . The connectors are considered electrically short over the whole frequency range and the sum of their transfer impedances is assumed to be smaller than that of the cable. The transfer impedances of the joints are included in the transfer impedances of the connectors.~~

~~In spite of the fact that the cable is electrically long at higher frequencies, the transfer impedances can be added together without taking into account the phase shift of the cable.~~

~~In practice, the magnitude of the transfer impedances of the connectors and cable create difficulties in both describing and measuring the screening effectiveness of the complete cable assembly if:~~

- ~~a) the transfer impedances of the connectors dominate, the transfer function and transfer impedance of a cable assembly will normally increase linearly with the frequency; or~~
- ~~b) the transfer impedance of the cable dominates, the linearly increasing transfer function has a cut-off frequency f_c above which resonances occur. The cut-off frequencies for the near and far end transfer functions are different as shown in figure C.2.~~

~~When the transfer impedance of the cable dominates, the envelopes (Env) of the transfer functions are:~~

$$\text{Env}(|T_{ji}|) \approx \frac{|Z_f + Z_t|}{2 \times Z_{12} \times \left(1 + \frac{1}{f_{cf}^n}\right)}$$

~~where~~

$$f_{cf}^n = \frac{C}{\sqrt{\epsilon_{r2}} \pm \sqrt{\epsilon_{r1}} \times \pi L} = \frac{v_{\pm}}{\pi \times L} \text{ and } v_{\pm} = \frac{C}{\left| \frac{1}{v_{r2}} \pm \frac{1}{v_{r1}} \right|}$$

~~It should be noted that both the effective transfer impedance and the screening attenuation include the effect of the cable length.~~

~~In the formulae above, it is assumed that the transfer impedance of the cable is always dominant.~~

C.2 Test method

~~The line injection method, which is satisfactory for coaxial cables, can also be used for measuring the screening effectiveness of a coaxial cable assembly. The full circuit for a coaxial cable assembly is given in figure C.3.~~

~~For measurements at frequencies above 100 MHz, the injection circuit needs to fulfil three well-defined conditions:~~

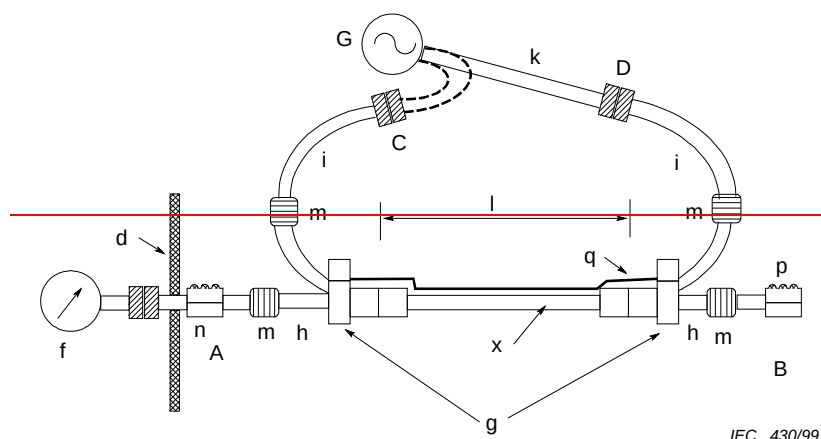
- ~~— constant characteristic impedance over the length of the test section;~~
- ~~— characteristic impedance matched to test instruments; and~~
- ~~— low or measurable insertion loss.~~

~~For the construction of the injection line, one or several parallel wires may be used with both ends of all wires connected to the central conductors of the coaxial feeder cables.~~

~~The characteristic impedance of the injection line shall be equal to that of the feeder cables, the generator and the load.~~

With the arrangement described, the generator and matched load on the injection circuit may be exchanged to perform either near or far end measurements, i.e. no manipulation of the cable assembly under test is required.

The full details related to this test method are given in clause 12 of IEC 61196-1.



A—is the cable assembly test circuit far-end relative to input at D (alternatively, near end relative to input at C)

B—is the cable assembly test circuit near end relative to input at D (alternatively, far end relative to input at C)

C—is the injection-circuit far end (alternatively, near end)

D—is the injection-circuit near end (alternatively, far end)

x—is the cable assembly under test

d—is the screened room wall with well-screened coaxial feed-through

G—is the generator (synthesizer, tracking generator, etc.)

f—is the test receiver (spectrum analyzer, network analyzer, etc.)

g—is the connection to injection wires

h—is a brass tube for additional screening of the cables fitted to the cable assembly under test

i—are injection wire feeder cables (length approximately 0,5 m each, low loss)

k—is the feeder cable from generator

l—is the length of cable assembly

m—are ferrite rings (length of each block approximately 100 mm)

n—is additional screening for the connection between screened room and cable assembly under test

p—is additional screening for terminating resistance of cable assembly under test

q—is the injection line

Figure C.3—Complete installation for practical screening effectiveness measurements