INTERNATIONAL STANDARD

IEC 61169-1

QC 220000

First edition
1992-09

Radio-frequency connectors

Part 1:
Generic specification –
General requirements and measuring methods

Connecteurs pour fréquences radioélectriques

Partie 1:
Spécification générique –
Prescriptions générales et méthodes de mesure

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Terminology, graphical and letter symbols

For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV).

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to publications IEC 60027: *Letter symbols to be used in electrical technology*, IEC 60417: *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets* and IEC 60617: *Graphical symbols for diagrams.*

* See web site address on title page.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIO-FREQUENCY CONNECTORS

Part 1: Generic specification – General requirements and measuring methods

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

4) The IEC has not laid down any procedure concerning marking as an indication of approval and has no responsibility when an item of equipment is declared to comply with one of its recommendations.

This standard has been prepared by Sub-Committee 46D: Connectors for r.f. cables, of IEC Technical Committee No. 46: Cables, wires, waveguide, connectors and accessories for communication and signalling.

The text of this standard is based on the following documents: IEC Publications 169-1, 169-1-1, 169-1-3, plus:

Six Months' Rule	Reports on Voting	Two Months' Procedure	Report on Voting
46D(CO)107 46D(CO)122 46D(CO)135 46D(CO)136 46D(CO)145 46D(CO)147 46D(CO)158	46D(CO)129 46D(CO)132 46D(CO)151A 46D(CO)155 46D(CO)169 46D(CO)170 46D(CO)187	46D(CO)140 46D(CO)183	46D(CO)152 46D(CO)202

Full information on the voting for the approval of this standard can be found in the Voting Reports indicated in the above table.

The QC number that appears on the front cover of this publication is the specification number in the IEC Quality assessment system for electronic components (IECQ).

RADIO-FREQUENCY CONNECTORS

Part 1: Generic specification – General requirements and measuring methods

1 Scope

This standard relates to connectors for r.f. transmission lines for use in telecommunications, electronic and similar equipment.

2 Object

This standard serves as a generic specification providing the basis for the sectional standards which apply to individual connector types. It is intended to establish uniform concepts and procedures concerning:

- terminology;
- standard ratings and characteristics;
- testing and measuring procedures concerning electrical and mechanical properties;
- classification of connectors with regard to environmental testing procedures involving temperature, humidity and vibration.

The test methods and procedures of the standard are intended and acceptance for type approval testing. They may also be adopted, by agreement between manufacturer and customer, to serve as a basis for acceptance tests.

3 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1169. At the time of publication of this standard, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 1169 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 27: *Letter Symbols to be Used in Electrical Technology.*

IEC 50: *International Electrotechnical Vocabulary.*

IEC 50(151): 1978, *Electrical and Magnetic Devices.*

IEC 68-1: 1988, *Environmental testing – Part 1: General and guidance.*

IEC 68-2-1: 1990, *Environmental testing – Part 2: Tests – Test A: Cold.*

IEC 68-2-2: 1974, *Environmental testing – Test B: Dry heat.*

IEC 68-2-3: 1969, *Environmental testing – Test Ca: Damp heat, steady state.*

IEC 68-2-6: 1982, *Environmental testing – Test Fc and guidance: Vibration (sinusoidal).*

IEC 68-2-11: 1981, *Environmental testing – Test Ka: Salt mist.*

IEC 68-2-13: 1983, *Environmental testing – Test M: Low air pressure.*

IEC 68-2-14: 1984, *Environmental testing – Test N: Change of temperature.*

IEC 68-2-17: 1978, *Environmental testing – Test Q: Sealing.*

IEC 68-2-20: 1979, *Environmental testing – Test T: Soldering.*

IEC 68-2-27: 1987, *Environmental testing – Test Ea and guidance: Shock.*

IEC 68-2-29: 1987, *Environmental testing – Test Eb and guidance: Bump.*

IEC 68-2-30: 1980, *Environmental testing – Test Db and guidance: Damp heat, cyclic: (12 + 12 hour cycle).*

IEC 68-2-42: 1980, *Environmental testing – Test Kc: Sulphur dioxide test for contacts and connections.*

IEC 68-2-47: 1982, *Environmental testing – Mounting of components, equipment and other articles for dynamic* tests.

IEC 68-2-54: 1985, *Environmental testing – Test Ta: Solderability testing by the wetting balance method.*

IEC 457-1: 1974, *Rigid precision coaxial lines and their associated precision connectors. Part 1: General requirements and measuring methods.*

IEC 617: *Graphical symbols for diagrams.*

ISO 370: 1975, *Toleranced dimensions – Conversion from inches into millimetres and vice versa.*

ISO 1000: 1981, *SI units and recommendations for the use of their multiples and of certain other units.*

4 Definitions

For the purpose of this standard, the following definitions apply:

4.1 *General, parts of connectors*

4.1.1 *(Electrical) Contact*

The state in which individual electrically conductive parts are in such close mechanical touch as to provide a low resistance path to electrical current in either direction.

4.1.2 *Contact*

The conductive element in a component which mates with a corresponding element to provide an electrical path (to provide electrical contact).

4.1.3 *Male contact*

Pin contact

A contact intended to make electrical engagement on its outer surface and which will enter a female (socket) contact.

4.1.4 *Female contact*

Socket contact

A contact intended to make electrical engagement on its inner surface and which will accept entry of a male (pin) contact.

4.1.5 *Hermaphroditic contact*

A contact which is intended to mate with an identical contact.

4.1.6 *Resilient contact*

A contact having elastic properties to provide a force to its mating part.

4.2 *Basic connector terms*

4.2.1 *Connector*

A component normally attached to a cable or mounted on a piece of apparatus (excluding an adaptor) for electrically joining separable parts of a transmission line system.

4.2.2 *Connector pair*

Two connectors having complementary mating faces and locking means, so as to be mateable and interlockable.

4.2.3 *Type*

Series

Terms characterizing the particular mating faces and locking means of a connector pair with regard to construction and dimension.

NOTE - The term "series" is sometimes used as an approximate synonym of "type" for designating the entirety of connector styles with identical mating face and locking means.

4.2.4 *Style*

A particular form or shape of connector, as well as a combination of connectors of the same type. Examples are: free and fixed connectors, both straight and right angle, within-type adaptors straight and right angle.

NOTE - For "adaptor", see 4.5.1 to 4.5.5: a "within-type adaptor" may also be considered as a particular style of a given type.

4.2.5 *Variant*

A variation of a style in particular details, such as cable-entry dimensions.

4.2.6 *Grade*

A qualification of a connector with regard to mechanical and electrical precision in particular with respect to a defined reflection factor.

4.2.7 *General purpose connector: Grade 2*

A connector making use of the widest permitted dimensional deviations (tolerances) so as still to guarantee minimum stated performance and intermateability.

NOTE - A requirement for the reflection factor may or may not be specified.

4.2.8 *High performance connector: Grade 1*

A connector for which limits of reflection factor are specified as a function of frequency. No tighter dimensional tolerances than those applicable to Grade 2 are normally specified. The manufacturer is responsible, however, for choosing tighter tolerances where necessary to ensure that the reflection factor requirements are met.

4.2.9 *Standard test connector: Grade 0*

A precisely made connector of a particular type used to carry out reflection factor measurements on Grade 1 and Grade 2 connectors, contributing only negligible errors to the measuring result.

NOTE - The standard test connector is often part of an inner-type adaptor which allows connection with a precision connector forming part of the measuring equipment.

4.2.10 *Precision connector*

A connector that has coincident mechanical and electrical reference planes, air dielectric, and has the property of making connections with a high degree of repeatability without introducing significant reflections, loss or leakage. It is intended for mounting on air-lines and instruments. Precision connectors can be of the hermaphroditic type, flange type or of the pin and socket type as stated in IEC 457-1: Rigid precision coaxial lines and their associated precision connectors, Part 1: General requirements and measuring methods.

4.2.11 *Laboratory precision connector (LPC)*

A precision connector without dielectric support for the centre conductor.

4.2.12 *General precision connector (GPC)*

A precision connector with self-contained dielectric support capable of supporting the unsupported centre conductor of an LPC and standard air-line with which it is mated.

4.3 *Constructional terms*

4.3.1 *Male connector*

Pin connector

A connector containing a male (pin) centre contact.

4.3.2 *Female connector*

Socket connector

A connector containing a female (socket) centre contact.

4.3.3 *Plug connector*

A connector featuring the active part of the coupling mechanism, i.e. the nut or bayonet ring, and which normally is a free connector.

NOTE - Depending on the particular type, a plug may be a male or female connector.

4.3.4 *Socket*

A connector complementary to the plug.

4.3.5 *Hermaphroditic connector*

A connector which mates with an identical connector.

NOTE - The coupling (locking) means need not be hermaphroditic.

4.3.6 *Free connector*

A connector for attachment to a free end of a cable. It is normally a plug.

NOTE - If not specified as fixed, a connector is assumed to be free.

4.3.7 *Fixed connector*

A connector with provision for attachment to a mounting surface. It is normally a socket.

4.3.8 *Triaxial*

A transmission line comprising three concentric conductors having a common axis and with each conductor insulated from the other two.

4.4 *Sealing*

4.4.1 *Sealed connector*

A connector employing a seal capable of fulfilling specified gas-, moisture- or liquid-tightness requirements.

4.4.2 *Barrier seal*

A seal preventing the passage of gases, moisture or liquids in an axial direction within the body shell of a connector.

4.4.3 *Panel seal*

A seal preventing the passage of gases, moisture or liquids between the fixed connector or adaptor body shell and the panel via the mounting hole(s).

NOTE - The sealing member is often provided as a discrete item.

4.4.4 *Mating face seal*

A seal preventing the passage of gases, moisture or liquids into the interface space of a pair of mated connectors.

4.4.5 *Hermetic seal*

A seal meeting the requirements specified on application of Test Qk of IEC 68-2-17: Environmental testing, Part 2: Tests, Test Q: Sealing.

4.5 *Miscellaneous terms and terms concerning measuring equipment*

4.5.1 *Adaptor*

A two-port device for joining two transmission lines having non-mating connectors.

4.5.2 *Fixed adaptor*

An adaptor with provision for attachment to a mounting surface.

NOTE - If not specified as fixed, an adaptor is assumed to be free.

4.5.3 *Within-type adaptor*

An adaptor for use between two or more connectors all of the same type.

4.5.4 *Inter-type adaptor*

An adaptor for use between two or more connectors of different types.

4.5.5 *Standard test adaptor*

An inter-type adaptor for test purposes, having a standard test connector at one end and a precision connector at the other end.

4.5.6 *Standard air line*

A homogenous air dielectric transmission line having the smallest possible irregularities in diameter and straightness of conductors, no self-contained supports for the inner conductor and using non-magnetic material with good conductivity.

4.5.7 *Reference line*

An air line similar to the standard air line but with dielectric support of the inner conductor, and with a design such that the internal reflection factor is kept at a minimum within the frequency range made use of for measurements.

4.5.8 *Cable simulator*

A section of precise transmission line with accurate characteristic impedance, in general a precision cable, to which the connector under test is attached in such a way that the transition from line to connector simulates as precisely as possible the normal state of the connector attached to an appropriate cable (in particular with regard to reflection factor and reactive disturbances).

4.5.9 *Proof coupling torque*

The maximum torque to be applied to the screw-coupling mechanism of a specific connector series for testing the mechanical strength of the coupling mechanism.

4.5.10 *Normal coupling torque*

The maximum/minimum values of torque to be applied in normal use to the coupling of screw type connectors.

4.5.11 *Engagement and separation torque*

The torque required to overcome friction, compression of springs, etc. during the engagement and separation of connectors with rotary type coupling mechanisms before or after complete engagement. This is intended to check for undue tightness of threads, burrs on bayonet-cams, freedom of rotation of coupling rings, etc.

4.6 *General electrotechnical terms*

NOTE - The following terms and definitions are taken from IEC 50(151): International Electrotechnical Vocabulary (IEV), Chapter 151: Electrical and Magnetic Devices, where they are numbered 151-04-01, 151-04-02 and 151-04-03, respectively. The note added to 3.6.1, nominal value, is for the purpose of this standard.

4.6.1 *Nominal value*

A suitable approximate quantity value used to designate or identify a component, device or equipment.

NOTE - It follows from the definition that a nominal value is not subject to tolerances.

4.6.2 *Limiting value*

In a specification, the greatest or smallest admissible value of one of the quantities.

4.6.3 *Rated value*

A quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment.

5 Units, symbols and dimensions

5.1 *Units and symbols*

Units, graphical symbols, letter symbols and terminology shall whenever possible, be taken from the following publications:

IEC publications:

27: *Letter symbols to be used in electrical technology.*

50: *International Electrotechnical Vocabulary (IEV).*

617: *Graphical symbols for diagrams.*

Other publication:

ISO Standard 1000 (1981): *SI units and recommendations for the use of their multiples and of certain other units.*

5.2 *Dimensions*

5.2.1 *Details to be provided in relevant specifications*

Each relevant specification shall provide:

i) sufficient dimensional information on the mating faces of general purpose and standard test connectors as to ensure intermateability and compliance with performance requirements: crimping dies, when used, shall be in accordance with the dimensions shown in IEC 803;

ii) information on the connector envelope maximum dimensions to enable the user to accommodate the connectors in his equipment.

The essential purpose of the drawings is to ensure mechanical interchangeability and adequate electrical performance: they are not, however, intended to restrict details of construction which do not affect interchangeability or performance, nor are they to be used as manufacturing drawings.

NOTE - Equipment designers should work to the limits stated in the outline drawings and not to the dimensions of individual specimens.

5.2.2 *Dimensional units to be used in specifications*

The dimensions and tolerances shall be given in both millimetres and inches. The original system of units shall be stated.

Independent of the system of units, the highest accuracy required by the dimensions shall be such that the values, the first digit of which is 1 or 2, shall not comprise more than five digits, those with the first digit being 3 to 9 shall not have more than four significant digits. In any case, the precision shall be limited to 1 µm or 0,00005 in.

5.2.3 *Conversion of dimensions given in inches into millimetres and vice versa.*

During the conversion of the dimensions, in principle they shall be rounded to the nearest 0,001 mm or 0,00005 in. Where, however, mechanical and electrical considerations permit, the rounding shall usually be to the nearest 0,01 mm or 0,0005 in. This also holds for the conversion between the systems of units after having made the exact calculation according to ISO Standard 370: Toleranced dimensions, conversion from inches to millimetres and vice versa.

A note shall be added to each specification reading:

"The values for the dimensions in...1...derived from these in...*...are not necessarily exact according to ISO Standard 370: Toleranced dimensions – Conversion from inches into millimetres and vice versa. They are, however, to be considered as acceptable rounded values with regard to accuracy.

NOTE - For more details, see 9.1.3 of IEC 1169-1."

6 Standard ratings and characteristics

The ratings and characteristics applicable to each connector type and style shall be stated in the relevant specification. They should normally cover:

- a short description of the connector construction stating in particular the inner diameter of the outer conductor and, if applicable, the cable types preferable to be used with the connector;
- the reflection factor as a function of frequency for the different grades (if applicable) together with the conditions for which it is valid;
- the working voltage at different altitudes (pressures);
- the climatic categories;
- any other rating or characteristic applicable.

7 Classification into climatic categories

The classification of connectors with regard to climatic conditions is based on IEC 68-1: Part 1: General and Guidance, and indicated by a series of three sets of digits separated by oblique strokes corresponding respectively to tests at low temperature (minus sign not shown), high temperature and the number of days of exposure to damp heat, steady state.

1 Millimetres or inches to be entered as applicable.

The climatic severities to be prescribed by the relevant specification shall preferably, but not necessarily, be selected from the following preferred values:

Low temperature	–40 °C, –55 °C
High temperature	85 °C (category 085), 125 °C and 155 °C
Duration of damp heat, steady state	4 days (category 04), 21 and 56 days

The following two groups are recommended as preferred climatic categories for r.f. connectors:

40/085/21

55/155/21

8 IEC type designation

The purpose of the IEC type designation is to identify a particular connector within the scope of IEC r.f. connector standardization. It is not intended to include information in excess of this. In practice, it is usually necessary to identify a manufacturer's product because, although complying with the IEC standard, there may be features not covered by the standard.

Connectors complying with the relevant specification shall be designated by the following indications and in the order given:

a) the number of the specification;

b) the letters "IEC";

c) additional identification as indicated in the relevant specification.

NOTE - When an IEC type designation is used, either for the marking of the product or in a description of the product, it is the responsibility of the manufacturer to ensure that the item meets the requirements of the relevant specification. The IEC as a body cannot accept responsibility in this matter.

9 Test Methods

9.1 *General*

This section comprises the description of electrical and mechanical measuring methods, environmental conditionings and testing procedures to be used and acceptance for type testing, but which are also applicable to other testing purposes. In general no requirements are directly specified. However, where appropriate, one or more preferred severities are given.

The relevant specification shall prescribe those tests, measuring methods and procedures, taken from the library of tests as contained in this chapter, needed for a specific product, together with the appropriate severities and requirements.

For technical reasons some of the tests have to be carried out in a definite sequence on the same specimens. Separate specimens may be required for different sequences. Since, for some tests the specimens undergo a treatment which excludes them from being sold, it is an economic measure to form appropriate test groups.

A schedule of test groups taking into account the above is shown in annex A. This schedule is expected to be applicable, in principle, to all types of connectors, deleting those tests or sequences not required for a particular type or style.

According to the schedule, all specimens of a test sample should be submitted to the first group of tests. The sample is then split up into the required number of equal sub-samples of not less than four pairs of connectors, unless otherwise specified.

9.1.1 *Standard conditions for testing*

Unless otherwise specified, the following conditions shall apply:

- tests shall be carried out under standard atmospheric conditions for testing as specified in IEC 68-1;
- before measurements are made, the connectors shall be preconditioned under standard atmospheric conditions for testing for a time sufficient to allow the entire connector to reach thermal stability.
- recovery conditions for the interval after a conditioning and the next measurement or test shall be in accordance with IEC 68-1.

The test schedule is shown in 10.3 and details of conditioning in 9.4.

When a nominal value only is given for an applied stress and/or the duration of application, the specified value shall be taken to indicate the minimum test severity to be applied.

The test shall be carried out with connectors as received from the supplier. In no case shall the contact parts be cleaned or otherwise prepared prior to tests, unless explicitly stated in the specification.

If it is required that a cable shall be attached to a connector, this shall be done in accordance with the connector manufacturer's instructions (normally supplied with the connectors).

Mated sets of connectors shall be fully engaged and screw-coupled connectors shall be tightened to the normal coupling torque quoted in the relevant specification.

When mounting is required in a test, the connector shall be securely mounted on a rigid plate of suitable material, using a clamp for free connectors or the normal fixing for fixed connectors. The dimensions of the mounting plate shall be such that the contour of the specimen is exceeded.

Mounting and arrangement of cables/wires for dynamic tests such as bump, vibration and shock, shall be in accordance with IEC 68-2-47. Unless otherwise specified in the relevant specification cables/wires shall be clamped to the test table in axial alignment at a distance of 90 mm ± 10 mm from each cable outlet. The free end of the cable shall be restrained from rotation by clamping to a rigid support.

Unless otherwise indicated in the relevant specification the effects of gravitational force and the direction and level of the prevailing magnetic field may be disregarded when carrying out dynamic tests.

In the case of mounted connectors subjected to environmental conditioning, care shall be taken to ensure that the surface finish of the mounting plate is compatible with that of the connector body so that electrolytic corrosion due to contact of dissimilar metals is avoided. For sealed connectors the mounting shall take the form of a suitable test jig so that without disturbance of the panel seals, the leakage rate may be measured at the conclusion of the recovery period after the environmental conditioning. The back-of-panel portion of such fixed connectors, when appropriate, shall be protected. The free ends of cable shall be protected against the ingress of moisture.

For tests involving exposure to high temperature – usually the upper temperature category as in the climatic sequence, rapid change of temperature and high temperature endurance, a cable with an appropriate temperature capability should be used. The upper temperature limit of the cable specified may, however, be less than of the connector.

9.1.2 *Visual inspection*

Visual inspection shall include a check on:

a) The marking:

it shall be correct in accordance with 11.2 and be legible after any of the specified tests.

b) The manufacture:

it shall have been carried out in a careful and workmanlike manner.

c) Deterioration after electrical, mechanical and climatic tests:

unless otherwise specified, there shall be no visible deterioration likely to affect the performance.

d) The marking on the package:

it shall be in accordance with 11.2.

9.1.3 *Dimensions*

The dimensions shall be checked and shall comply with those specified by the relevant specification.

Any suitable method may be used except that gauges shall be used when specified by the relevant specification.

9.1.3.1 *Outline dimensions*

The outline dimensions shall comply with those specified in the relevant specification. When specified as a lot-by-lot inspection, this requirement may be demonstrated prior to final assembly.

9.1.3.2 *Piece-parts-with-materials*

One set of piece-parts supplied to the requirements of the relevant specification shall be checked with compliance with the drawings quoted on the qualification approval application or certificate.

9.1.3.3 *Mechanical compatibility*

The dimensions of the mating face shall be in accordance with the mating face drawings prescribed in the relevant specification.

Use of compatibility gauges is optional. When used, specimens shall accept the gauges.

9.2 *Electrical tests and measuring procedures*

9.2.1 *Reflection factor*

9.2.1.1 *General considerations*

The reflection factor of r.f. connectors shall be measured with the test specimen mated with a standard test connector. Adaptors shall be mated with standard test connectors on both sides.

The relevant specification for a particular connector shall also specify the pertinent standard test connector (connector of Grade 0). Mated pairs of standard test connectors shall exhibit closest uniformity of characteristic impedance throughout the pair inclusive of the transitions to precision lines or cables.

Cable connectors shall be attached to an appropriate cable in accordance with the instructions supplied by the connector manufacturer. The cable to be used shall preferably be of the close tolerance type. Alternatively the use of a cable simulator is permitted.

Time-domain reflectometry (TDR) shall be used to check the homogeneity of the measuring set-up, to localize imperfections and to examine the accuracy of the characteristic impedance of the sections of coaxial lines used.

The reflection factor shall be expressed as a function of frequency. Measurements shall usually be made in the frequency domain, preferably by using a swept-frequency generator. Measuring in the time domain and converting to frequency domain may be suitable up to frequencies of approximately 1 GHz and has the particular advantage of permitting the separation of reflections arising from the connector under test from other reflections in the system. This is more difficult to achieve, in particular at low frequencies, when measuring in the frequency domain.

If spot frequency, as distinguished from sweep-frequency, techniques are used, appropriately small frequency increments shall be employed. Spot-frequency techniques are not satisfactory for error recognition methods, unless the generator (normally automatically controlled) permits very small increments of frequency.

Examples of appropriate equipment for measuring the reflection factor as a function of frequency include radio-frequency bridges, directional couplers and slotted lines. Measuring set-ups using this equipment without special provisions for recognition of errors originating from different defects are, in general, only satisfactory for reflection factors greater than 0,05 (considering that the measuring uncertainty should not be greater than 10 % of the quantity measured).

For testing connectors with specified reflection factor limits lower than 0,05 the use of a set-up permitting the recognition of error contributions, and thus permitting the evaluation of the relevant reflection, will in general be necessary.

There are some computer controlled automated measurement systems having enhancement routines with error correction models that reduce the measurement uncertainty in reflection factor to the point where further recognition methods are not required.

9.2.1.2 *Information to be given in the relevant specification*

a) limits for the reflection factor as a function of frequency appropriate to the grade;
b) measuring accuracy;
c) details of the standard test connector;
d) necessary characteristics of the appropriate cable;
e) any deviation from the standard test method.

9.2.1.3 *Normal measuring methods*

9.2.1.4 *Ordinary measuring set-up*

Figure 1 shows a simple set-up, using either a bridge, a directional coupler or a slotted line, with which the recognition of errors from different sources is not normally possible. In this figure, the principle locations where reflections may occur are marked with B, C and D, together with the associated reflection factors r_b, r_c and r_d. The reflection factor due to the connector under test is r_x.

The measuring port error r_b represents not only the reflection at that location but incorporates also bridge, coupler or slotted line residual errors.

Since the phases of the several reflected waves depend on the electrical lengths between the locations and, therefore, on the frequency, their contributions to the apparent total reflection factor are random. The root mean square value obtained, therefore, is:

$$r_{total} = \sqrt{r_x^2 + (r_b^2 + r_c^2 + r_d^2)}$$

As an example, typical values may be r_b = 0,018, r_c = r_d = 0,01. Assuming r_x = 0,05 this leads to:

$$\frac{r_{total}}{r_x} = 1,1$$

This represents an inaccuracy of 10 %. Single values at individual frequencies may, of course, be affected by much greater or smaller errors.

Although a swept-frequency generator is indicated in figure 1, this is not intended to preclude the use of spot-frequency techniques, taking into due account the warning expressed in 9.2.1.1.

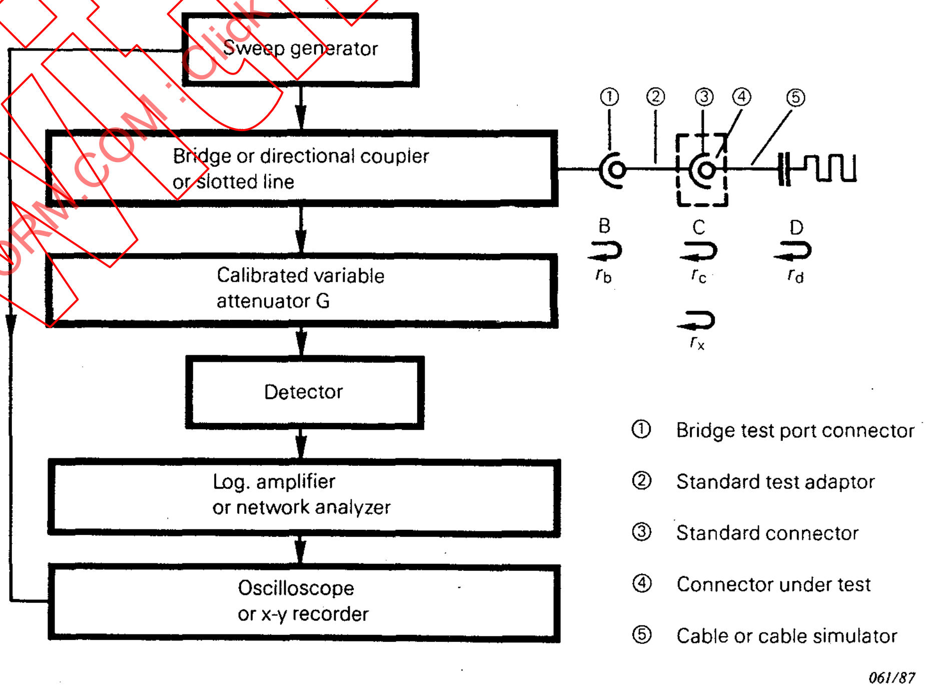


Figure 1 – Bridge, coupler or slotted line method without error recognition

9.2.1.5 *Two-connector procedure*

A special procedure, called the two-connector procedure, uses as test set-up two, as far as possible identical, test specimens interconnected back to back by a section of cable previously selected for accuracy and uniformity of characteristic impedance. While not permitting the recognition of errors, this procedure allows identification with good probability whether appreciable disturbances are present.

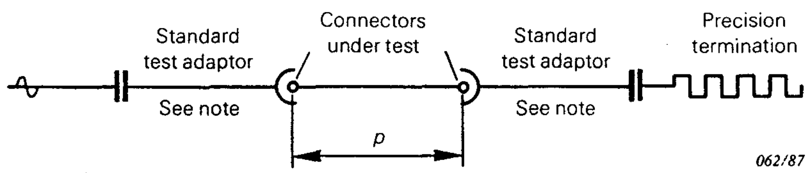
The procedure is illustrated in figure 2. It makes use of the phenomena that for two identical test specimens, which have also equal reflection factors as a function of frequency, the reflections from the two connectors cancel each other each time the distance *p* between them corresponds to an odd number of quarter wavelengths, and they add numerically to double their individual value if *p* equals an even number of quarter wavelengths of the wave in the interconnecting section *p*. Complete cancellation is a fairly reliable criterion for both the exact equality of the reflections from the two connectors and the absence of spurious reflections in the system.

In practical applications, the loss in the cable section *p* prevents the backward waves, resulting from equal reflection factors, from producing complete cancellation at the nodes. Unequal reflections manifest themselves as unequal minima when the connector assembly is reversed. In general, low maximum values (low reflection factor) with minimum values that do not change with reversal of the assembly, are acceptable. However, maximum values corresponding to reflection factors in excess of specified data, or considerable change in minimum values when the assembly is reversed should result in both connectors and cable being inspected before further tests are resumed.

The interconnecting cable of the connectors shall consist either of a prescribed cable of verified performance or an adequate cable simulator. The cable shall be no longer than is necessary with regard to the lowest frequency at which the reflection factor is to be measured. Several lengths *p* may be advisable for a wide frequency range and also if results are required at frequencies not covered by the series of anti-nodes.

As a check of the accuracy of the system, it is recommended to repeat the measurements with the connector assembly reversed between the standard test connectors.

The two-connector procedure may be used in conjunction with bridge, directional coupler or slotted line measuring methods. In the following, the latter method is described in some detail.



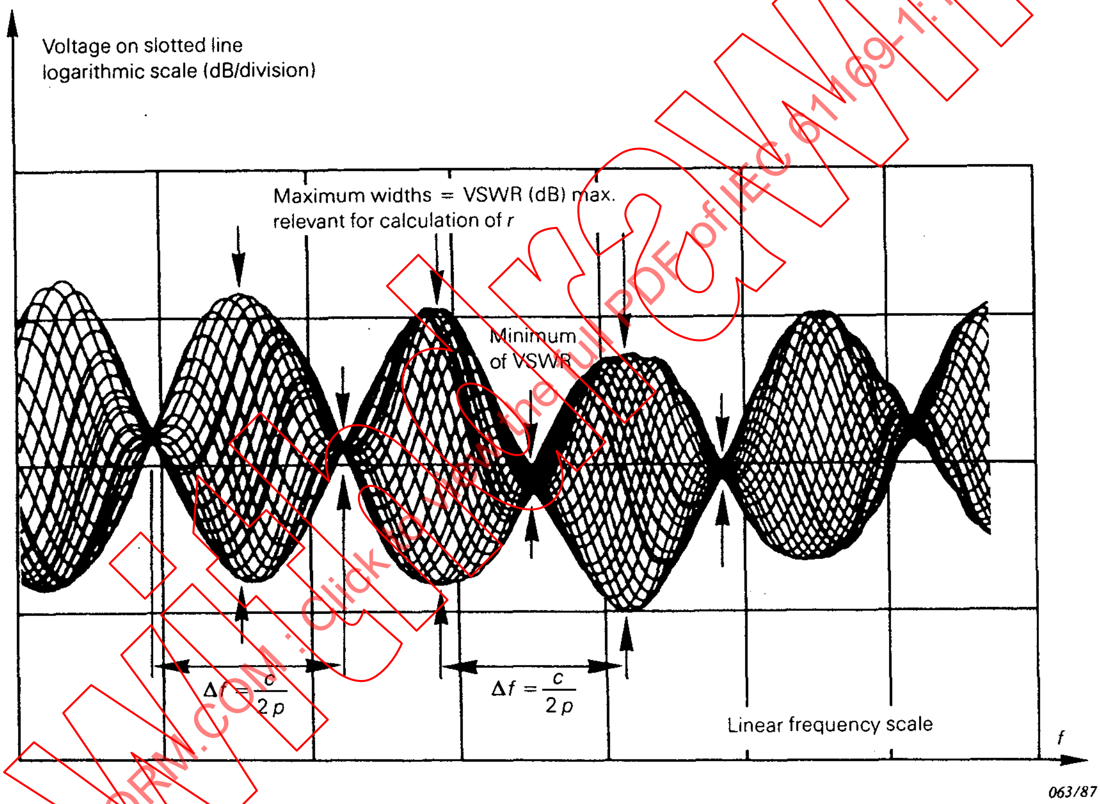
NOTE - Instead of using standard test adaptors, standard tests connectors may be directly used on the generator port and the precision termination.

Figure 2 – Measuring set-up for two connector procedure

Figure 3 shows the x-y-plot of the voltage on the slotted line, preferably using a logarithmic scale graded in decibels, as a function of frequency with the probe position as a parameter (the probe is simply moved by an appropriate amount after each frequency sweep). The display of the curves permits the envelopes to be drawn. Thus, the minimum widths of the display may be judged. The maximum widths of the envelope correspond to the voltage standing wave ratio (VSWR) from which the reflection factor at the particular frequency is derived.

The numerical value of the reflection factor *r* corresponding to the maximum is given by the formula:

$$\text{for a single connector: } r = \frac{1}{2}\ \frac{\text{VSWR} - 1}{\text{VSWR} + 1}$$



c = wave propagation speed in section *p*

Figure 3 – Voltage on slotted line as a function of frequency with probe position as parameter

9.2.1.6 *Measuring methods providing error recognition*

9.2.1.6.1 *Using a bridge*

In order to achieve the possibility of error recognition, two modifications are applied to the normal measuring set-up in figure 1. These include providing adequate lengths of the lines from the bridge port B to the test assembly at C, and from the test assembly to the matched load at D. Furthermore, the termination at the reference port A of the bridge is given a value such that, assuming the test port is terminated by the exact nominal characteristic impedance, a known reflection factor r_b of, for example, 0,1 (return loss 20 dB) would result. The set-up is shown in figure 4. The length l_2 should be made at least five times l_1.

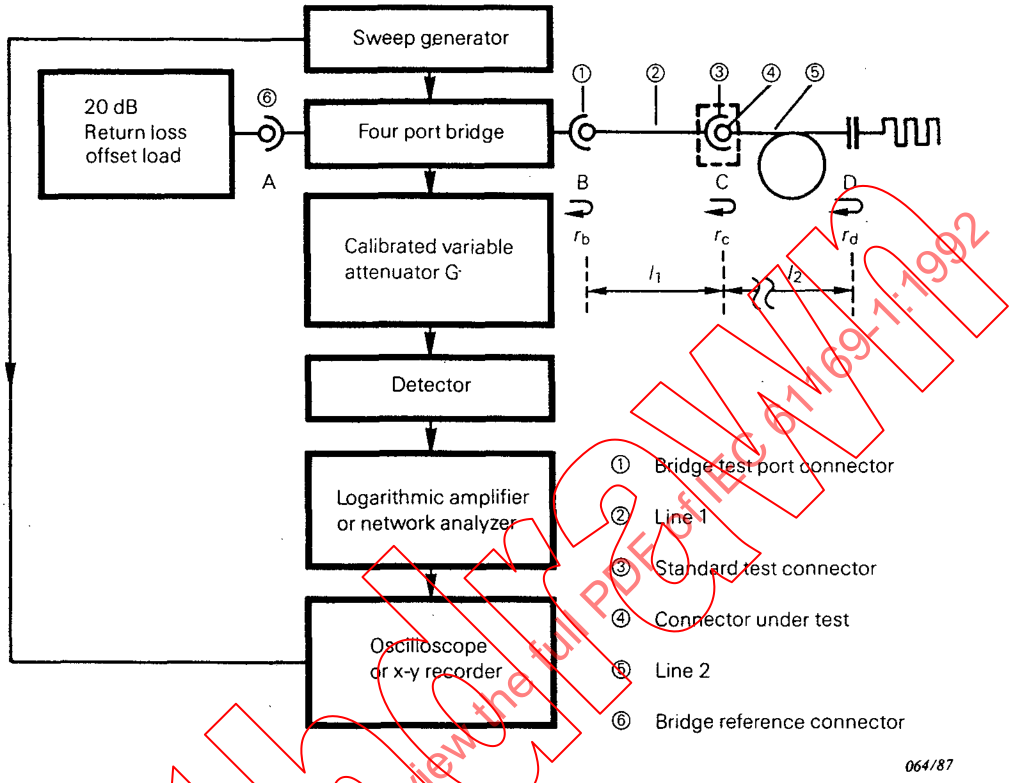


Figure 4 – Bridge method with error recognition

This method produces a plot of the total (resulting) reflection factor as a function of frequency illustrated in figure 5. At point B, the summation of the three complexors (phasors), representing the reflection factors, is given by:

$$\underline{r}_{tot} = \underline{r}_b + \underline{r}_c + \underline{r}_d$$

where

$\underline{r}_b$ is due to the intentional and known mismatch of the bridge at the port B and is more or less constant in amplitude. Slight deviations are caused by internal bridge errors and by the influence of non-zero line lengths between the bridge-elements and the test and reference ports B and A.

$\underline{r}_c$ includes the reflection factor $\underline{r}_x$ of the connector under test and that of the standard test connector. By its rotation relative to the complexor $\underline{r}_b$ it causes the ripple E, as shown in figures 5 and 6b.

$\underline{r}_d$ is the reflection of the termination at the end of line 2 and is responsible for the ripple F which is five times faster than the ripple E if the electrical lengths correspond exactly to $l_2 = 5\ l_1$.

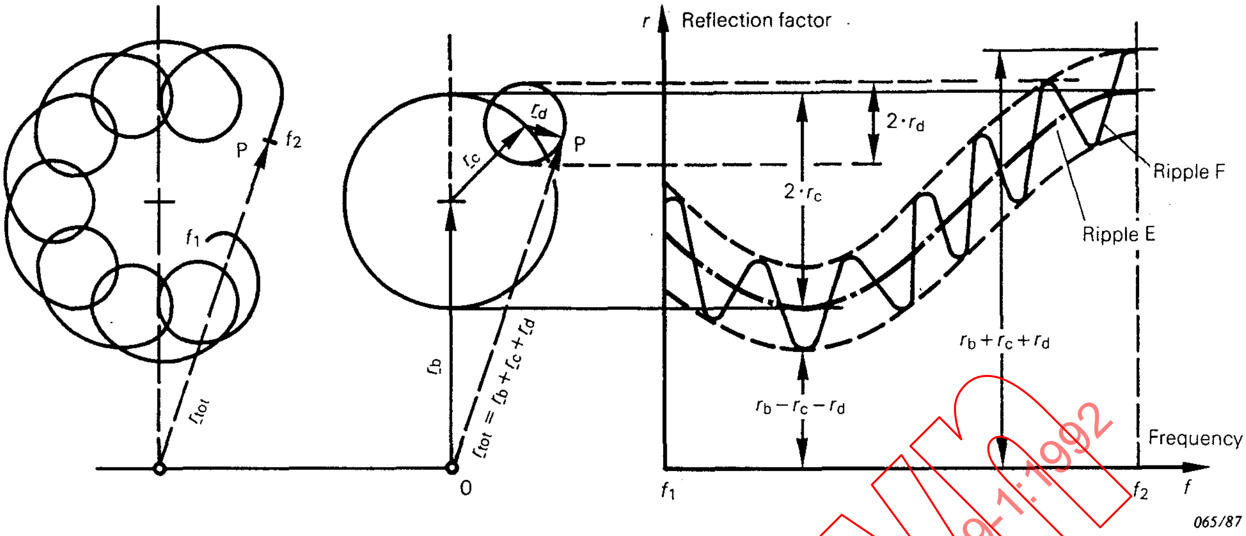


Figure 5 – Complexor (phasor) chart according to the set-up in figure 4

When using logarithmic detection, the display of the curve on an x-y-plotter will show the resulting return loss in decibels as ordinate, frequency as abscissa. An example is represented in figure 6a. The conversion into reflection factor may be carried out by using an overlay scale as shown on the right of figure 6a, or by other suitable means. The extraction of $r_c(r_x)$ is done by calculation, for which figures 6b and 6c, are given as guidance.

The offset reflection factor r_b must be greater than the sum $r_c + r_d$ to prevent ambiguity of the total reflection curve.

The swept-frequency range and the electrical lengths of both lines should be chosen such that there is a sufficient number of ripples to determine the reflection factor curve. With a 200 mm air line l_1 between bridge test port at B and the standard test connector at C, one r_c-ripple (E) period corresponds to a 750 MHz variation in the frequency axis of the display.

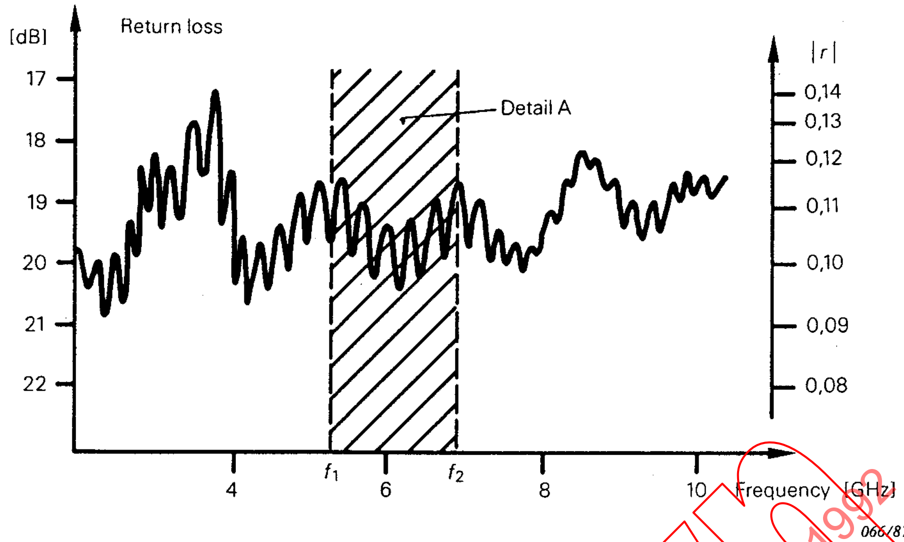


Figure 6a – Return loss measurement, example according to the set-up in figure 4

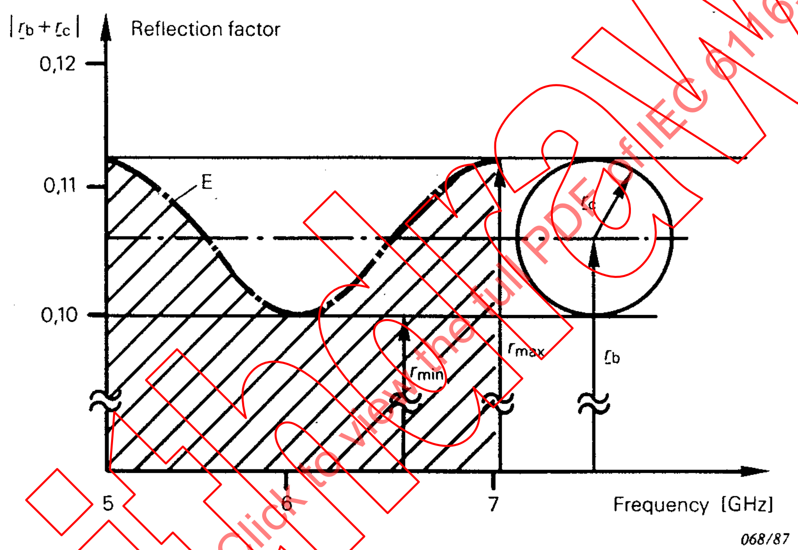


Figure 6b – Detail A, converted to reflection factor. Elimination of r_d by averaging out F. Ordinate values of shaded area correspond to the sum $r_b + r_c$

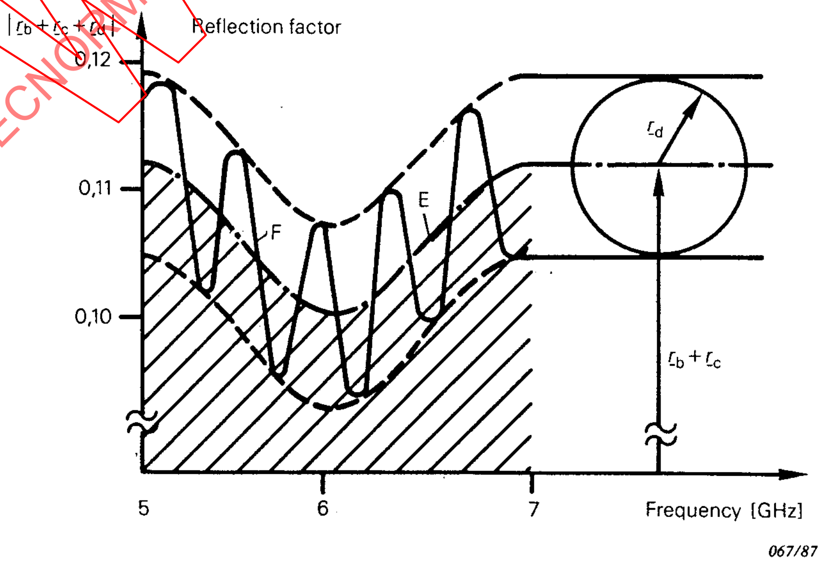


Figure 6c – Extraction of r_c (ripple E) by dividing the difference $r_{max} - r_{min}$ by 2. r_c is the reflection factor of the connector under test (including the reflection of the standard test connector at C in figure 4)

9.2.1.6.2 *Using a directional coupler*

When using a directional coupler instead of a bridge, the line l_1 (from B to C) shall be replaced by a broadband impedance discontinuity acting as a low loss partial reflection and transmission element. This takes the form of a coaxial line partially filled with low loss dielectric foam as shown in figure 7, with a sharp discontinuity at B: r_{offset} ~ 0,1 (~ 20 dB return loss), matched to Z_o at its output.

The measuring process is similar to that described under 9.2.1.6.1 for the bridge method with error recognition.

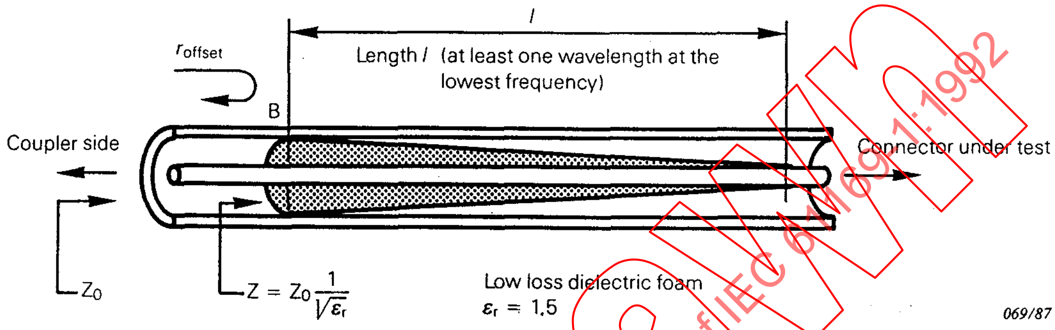


Figure 7 – Broadband impedance discontinuity acting as a low loss partial reflection and transmission element

9.2.1.6.3 *Alternative set-up for special purposes*

If the connector at the end of line l_1 at C is the test specimen to be measured, line l_2 can be replaced by an absorptive sliding termination. Periodic variation of the load element position (at least by one-half wavelength) during the slow sweep action simulates the long line effect of the line l_2 and results in an equivalent ripple F as in figure 6a.

NOTE - Resonance reflections can be detected when using any of the three procedures described above. Such reflections create sharp irregularities in the reflection sum curve.

9.2.1.6.4 *Remarks on remaining errors*

There are a few remaining errors not eliminated by the procedure described:

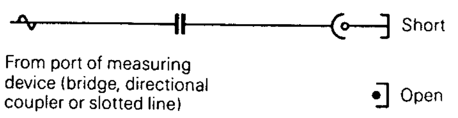
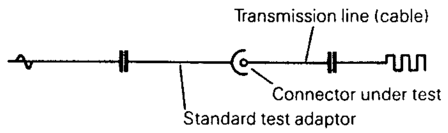
– error caused by deviations of characteristic impedance of coaxial lines. This error can be minimized by selecting the correct impedance using time-domain reflectometry;

– error of calibration attenuator G, shown in figures 1 and 4;

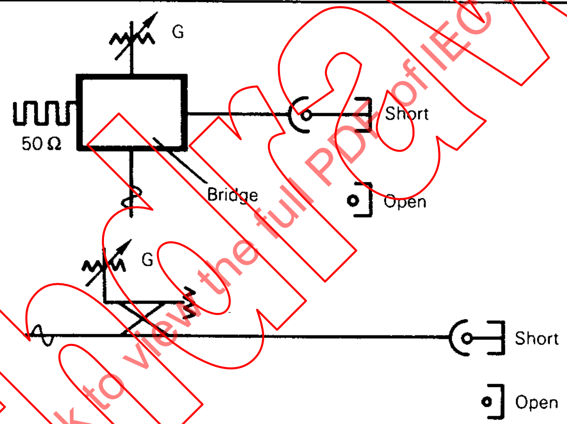
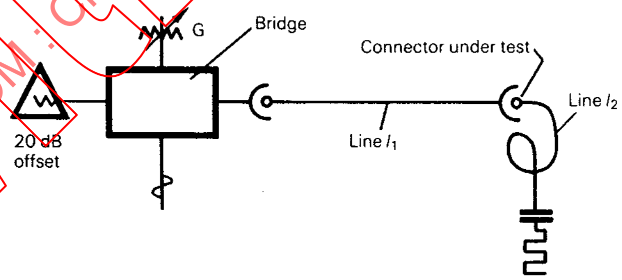
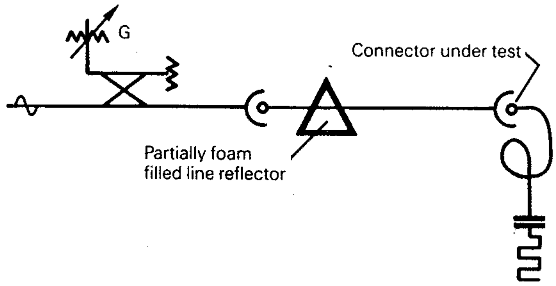
– standard test connector error. This may be minimized by making the standard test connector a part of a precision air line having the same diameter;

– influence of air line l_1 attenuation between B and C on the reflection factor value r_c measured. If this attenuation is not negligible, twice its value (in decibels) has to be subtracted from the return loss before computing the true reflection factor r_c.

9.2.1.7.2 *Methods without error recognition according to 9.2.1.1*

Purpose	Test method	Notes
Calibration for generating a grid of constant return loss curves		Alter attenuator G setting from 0 dB by convenient steps and plot corresponding return loss curves
Measusring of the reflection factor of a single connector according to 9.2.1.2		Measurements are carried out on connectors fitted to selected and verified transmission line in accordance with manufacturer's assembly instructions. Alternatively, a cable simulator may be used

9.2.1.7.3 *Methods with error recognition according to 9.2.1.4*

Purpose	Test method	Notes
Generation of a grid of decibel return loss calibration curves		Terminate reference port with matched load. Draw the average trace between open and short for 0 dB and plot the return loss grid by altering the attenuator G setting in convenient steps
Measuring the reflection factor sum according to figures 6a to 6c, page 48 and deduction of reflection factor r_c		Initial position of attenuator G at 0 dB. Introduce 20 dB offset at reference port of bridge
Measuring the reflection factor sum according to figures 6a to 6c and deduction of reflection factor r_c		Initial position of attenuator G at 0 dB. Introduce line reflector with impedance step at directional coupler side
Correction of measured return loss, if necessary	Check air line attenuation	Real return loss: measured return loss minus two times line l_1 loss

9.2.1.8 *Method of time-domain reflectometry (TDR)*

9.2.1.8.1 *Theoretical considerations*

Assuming the incident signal has the ideal form of a step function the reflected $s(t) = r(t)$ is converted to the complex reflection factor as a function of frequency by:

$$r(\omega) = \mathrm{j}\omega \int_0^T s(t) \cdot \mathrm{e}^{-\mathrm{j}\omega t}\,\mathrm{d}t$$

where 0 to T is the time interval comprising the portion of $s(t)$ due to the reflection arising from the connector under test.

Restricting the upper frequency limit to values such that $\omega T < 1$, $\mathrm{e}^{-\mathrm{j}\omega t} \approx 1$, allows the expression to be simplified to:

$$r(\omega) \cong 2\pi f \int_0^T s(t) \cdot \mathrm{d}t = A \cdot f \qquad A = 2\pi \int_0^T s(t) \cdot \mathrm{d}t$$

Figure 8 shows an example of a time-domain reflectometer recording.

NOTE - As only the magnitude of the reflection factor is of importance the sign of the reflected signal integral is omitted. A positive sign results from an inductive series, a negative sign from a capacitive parallel disturbing element.

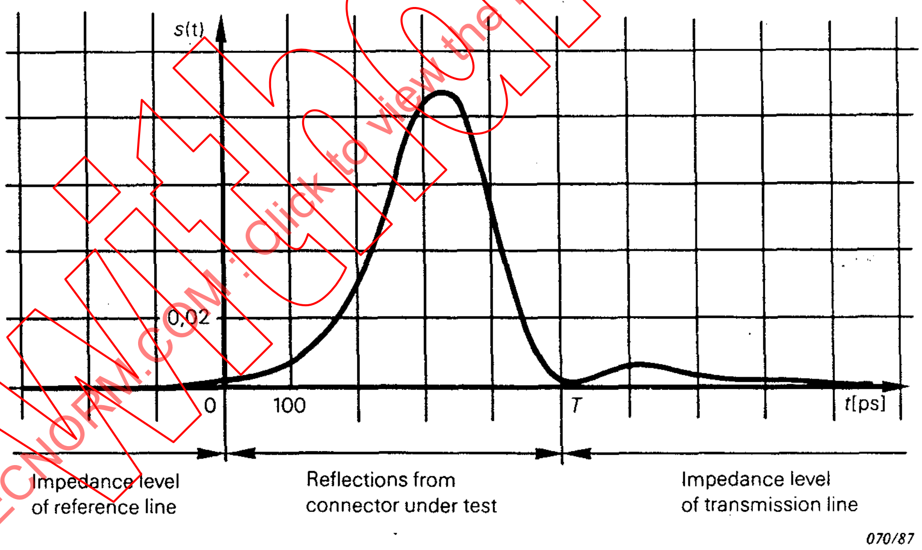


Figure 8 – Example of a time-domain reflectometer measurement recording

In the example, the surface under the curve from 0 to T is:

$$\int_0^T s(t) \cdot \mathrm{d}t = 17{,}5 \text{ ps}$$

Therefore at 100 MHz: $r = 0{,}011$.

9.2.1.8.2 *Measuring procedure*

The verification of the equipment and the elements used is carried out as shown in the first three boxes of the table in 9.2.1.7.1. The set-up for carrying out the measurement is illustrated by figure 9.

The reflection factor calculation, a permanent record of the reflected waveform shall be made (reading from the screen is usually not accurate enough).

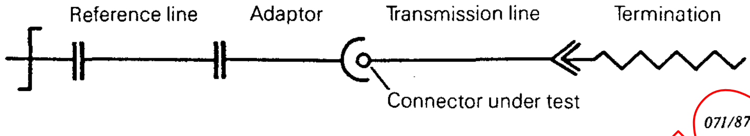


Figure 9 – Equipment set-up for the measurement of reflection in time domain

Both the time and the reflection factor scales of the TDR equipment shall be calibrated by independent references. For the time scale, this can be done by using air lines of known length, sliding short-circuits or by time standards. The reflection factor scale is calibrated by using known impedance mismatches or input signals of known amplitude. For routine calibration between measurements, open or short-circuiting is also satisfactory.

In addition to the calibration, the measuring equipment should be checked for the following sources of error:

– the step form shall be adjusted for minimum ripple and irregularities before the calibration;

– losses in air lines and equipment cables distort the incident step. Excessive lengths should be avoided;

– multiple reflections in the measuring system added to the reflection from the connector under test, especially if the system includes unmatched components. Their effect can be minimized by selecting the lengths of air lines and cables so that the reflections from different sources are separated in time;

– leaky connections or unshielded terminations may cause interference signals in the measuring system;

– errors are often due to an uncertainty in defining the line corresponding to zero reflection. This is particularly important if the reflected signals are small.

9.2.1.8.3 *Frequency range*

Assuming a maximum length of the connector under test of 50 mm and a step signal with a rise time of not more than 200 ps, the TDR method usually permits adequate accuracy up to 200 MHz, using the appropriate formula for the conversion into the frequency domain.

NOTE - A gradual increase instead of a sudden step of the input signal has, besides the restriction of frequency range, the effect of flattening the reflected signal and thus of lowering its amplitude, which in turn diminishes the accuracy.

9.2.1.8.4 When connectors are used with semi-rigid cable it may be desirable to stabilize the assembly by temperature cycling between –40 °C and 90 °C before carrying out the reflection factor measurement.

9.2.2 *Power rating*

9.2.2.1 *Definitions*

Power rating is the input power at which neither the peak working voltage nor the maximum dielectric temperature of the connector are exceeded, if the connector is terminated in its characteristic impedance.

The nominal value of voltage-limited power rating is defined as follows:

$$P_{u,\,max} = \frac{U^2_{max}}{2\,Z}$$

where

U_{max} is the peak working voltage

Z is the characteristic impedance

$P_{u,\,max}$ implies sinusoidal c.w. excitation

The nominal value of temperature-limited power rating is defined by the steady state power at which the inner conductor reaches its maximum temperature as per table 1 below (alternatively as per climatic category). The nominal value is stated for an ambient temperature of 40 °C.

Table 1

Dielectric material	Maximum inner conductor temperature
Polyethylene (LD-PE)	85 °C
Polytetrafluoroethylene (PTFE)	200 °C
Fluorinated ethylene propylene (FEP)	180 °C

9.2.2.2 *General measuring conditions*

Cable connectors shall be attached to the appropriate cable, as per manufacturer's instructions.

The specimen shall be placed horizontally in still air, allowing free air convection, and screened from the influence of other heat sources.

The test duration shall be long enough to establish thermal balance.

9.2.2.3 *Conversion Formula for Temperature*

Sometimes test conditions are such that the standard ambient temperature of 40 °C cannot be achieved and/or the maximum inner conductor temperature cannot be maintained. In this case, the following approximate formula should be used:

$$P = P_1 \left(\frac{t - T}{t_1 - T_1} \right)^{1,14}$$

where the range of values t_1 and T_1 is as follows:
t_1 from $(t - 15)$ to t
T_1 from 15 °C to 40 °C

T_1 = ambient temperature during test
T = standard ambient temperature (40 °C)
t_1 = inner conductor temperature under test
t = maximum inner conductor temperature (see table 1 of 9.2.2.1 or per climatic category)

P_1 = measured input power under conditions t_1 and T_1
P = power rating (temperature-limited)

9.2.2.4 *Measuring Methods*

Ideally, the specimen is terminated in its characteristic impedance and then fed with RF power until maximum working voltage or maximum inner conductor temperature is reached, but not exceeded. In practice, this is not very often possible, and the electrical and thermal conditions have to be obtained by other, equivalent, methods. The following three methods are described below:

direct method

ring Line method

resonance method

9.2.2.4.1 *Direct method*

Due to required generator output this method is limited to small/medium diameter components. There are no limitations in frequency range, other than those of the specimen itself.

Measuring circuit:

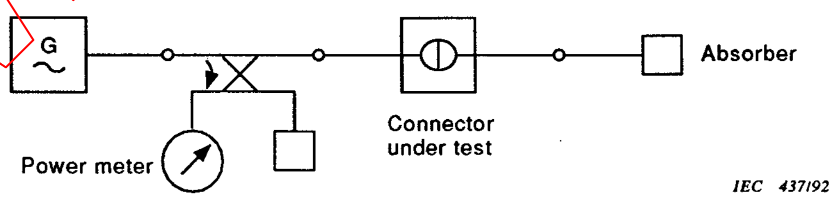


Figure 10 – Direct method

Mismatch results in measuring error as follows:

$$u = 100 \left[\frac{(1 + s)^2}{4\,s} - 1 \right] \text{ in } \%$$

s = line VSWR

u = maximum error

The maximum error occurs in the current minimum.

9.2.2.4.2 *Ring line method*

This method makes use of phase relations of a directional coupler, in connection with the resonance properties of a ring line. The characteristics of a directional coupler with matched ports 2, 3 and 4 are defined as follows:

Directivity $a_D = 10 \log \frac{P_3}{P_4}$ in dB

Coupling loss $a_K = 10 \log \frac{P_1}{P_3}$ in dB

Longitudinal Loss $a_{1,2} = 10 \log \frac{P_1}{P_2}$ in dB

Method with constant coupling

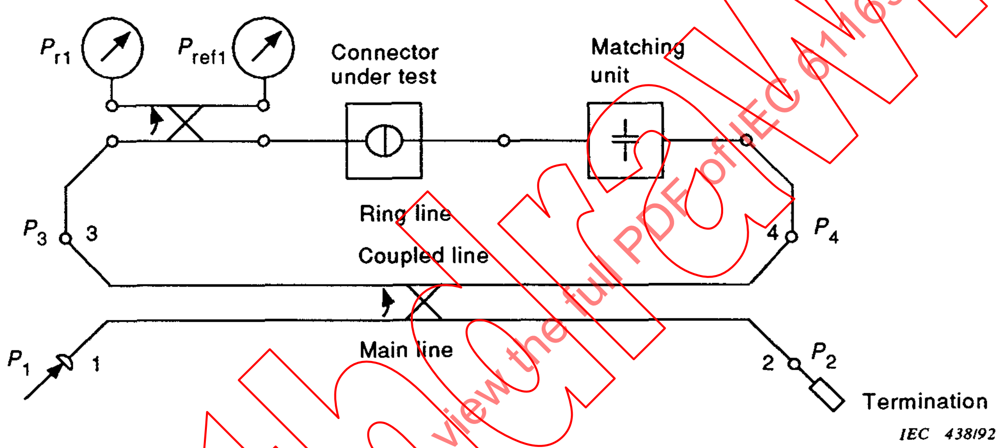


Figure 11 – Ring line method with constant coupling

The power circulating in the ring line is a multiple of the power P_1 fed into port 1 if the following conditions prevail:

the port 2 is low VSWR terminated;

the ring line is matched to the characteristic impedance of the side line (ports 3 and 4) of directional coupler;

the electrical length of the ring line is $1_{e1} = n \cdot \lambda_0$;

where n = a whole number;

λ_0 = free space wave length at measuring frequency.

The connector under test is in series with a directional coupler having calibrated power and reflection meters. The matching unit (e.g. a line segment with tuning screws) serves to compensate for residual ring line reflections.

The ratio of multiplied power to input power P_1 is generally as follows:

$$\frac{\text{Multiplied power}}{P_1} = \left(\frac{K}{1 - A\sqrt{1 - K^2}} \right)^2$$

where: $A = 10^{-a/20}$ transmission factor of the transmission line with $a =$ ring line loss in dB;

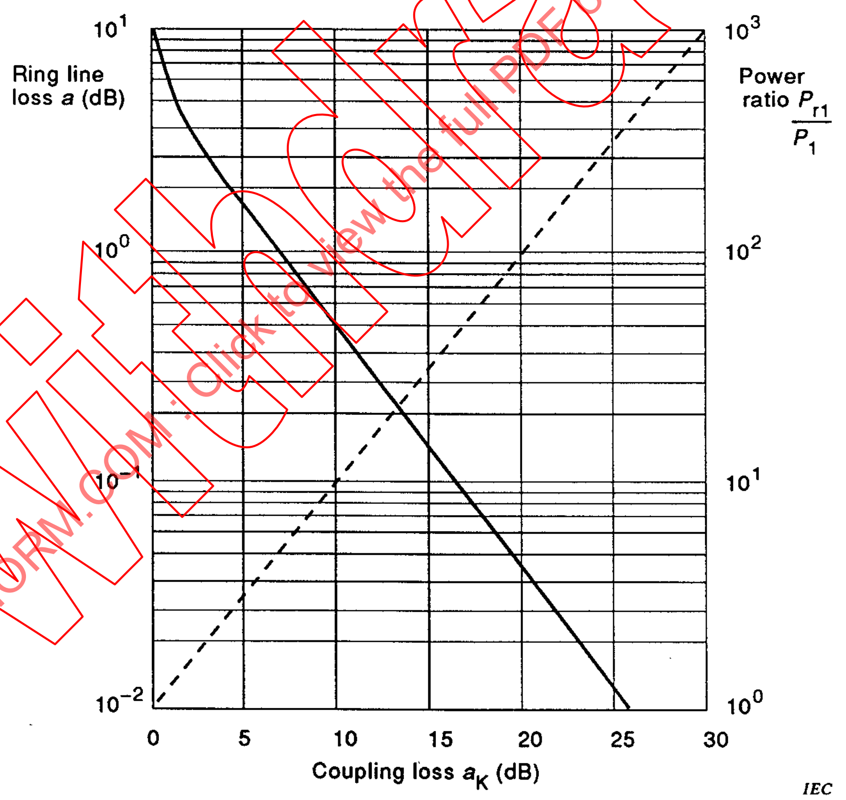
$K = 10^{-a_K/20}$ coupling factor of the main line directional coupler;

P_{r1} is maximum for $A^2 + K^2 = 1$;

In which case $\dfrac{P_{r1}}{P_1} = \dfrac{1}{K^2}$

In this case, the full input power P_1 feeds into the ring line. This condition is shown in figure 12.

If no coupler with $K = \sqrt{1 - A^2}$ is available for a given ring line loss, then the method with variable coupling may be used.



——— find optimum coupling for given ring line loss (1)

- - - - - - - find power ratio for that coupling loss value (2)

$a = 10 \log (1 - 10^{a_K/10})$

$\dfrac{P_{r1}}{P_1} = 10^{-a_K/10}$

Figure 12 – Method with variable coupling

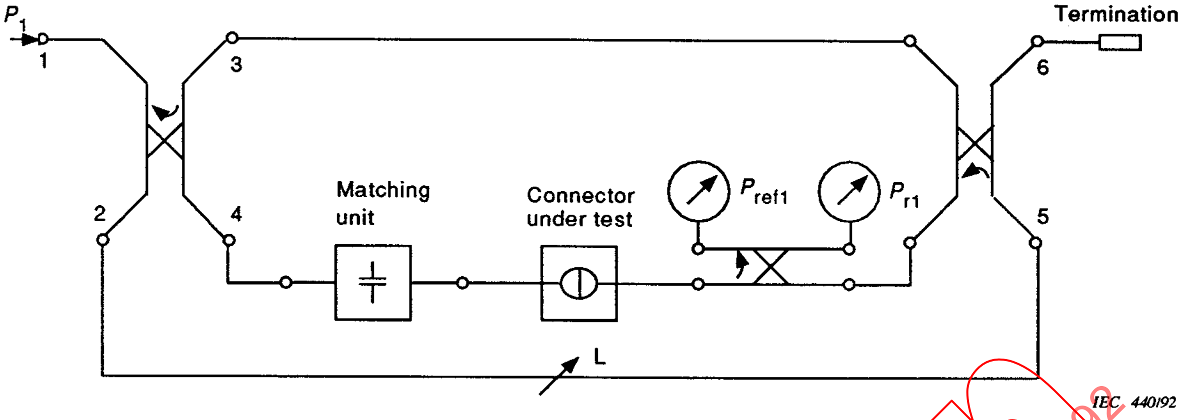


Figure 13 – Ring line method with variable coupling

By means of two 3 dB couplers plus a connecting line 2 – 5 of variable length it is possible to realize any required coupling level into ring line 3 – 8 – 7 – 4 – 3.

For a given coupling factor K the appropriate electrical length differential between ports 2 and 5 on one side and ports 3 and 8 on the other is as follows:

$$\Delta 1_{e1} = \frac{\lambda_0}{\pi} - \text{arc cos } K$$

The appropriate length differential is obtained by tuning the variable length line to the required coupling for maximum power multiplication.

NOTE - For low frequencies, long low loss lines are necessary.

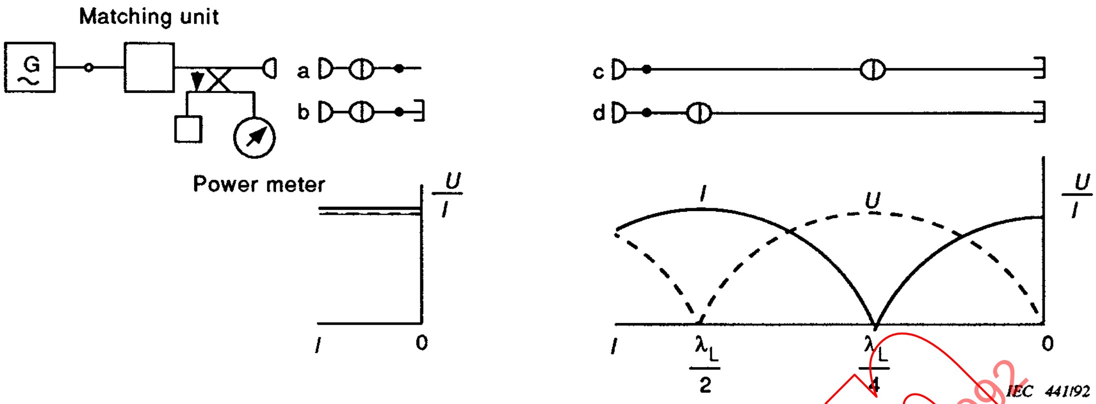
9.2.2.4.3 *Resonance method*

The connector under test is placed alternatively into both current maximum and voltage maximum by means of suitable circuitry. Input power is measured by means of a directional coupler arrangement. The characteristic impedance of the directional coupler's main line should correspond to the nominal value of the specimen.

According to its electrical length, the specimen acts as part of a resonance circuit, or as a transmission line with standing waves. In the short-circuited case only, the connector under test should be placed such that its distance from the short-circuited end is

$\frac{\lambda_L}{2}$ (for maximum current), respectively $\frac{\lambda_L}{4}$ (for maximum voltage), λ_L being the wave length on the line.

The power in the specimen is then: $P = 4\ P_1$
with P_1 = measured input power.



Electrical length of specimen*	≤ 0,03 λ_s		$> \frac{\lambda_s}{2}$	
Test for	voltage	current	voltage	current
Test circuit	a	b	c	d

* Including connecting leads λ_s = wave length in specimen

Figure 14 – Resonance method

To obtain a correct test result, the following shall be observed:

- for current test: prevent axial heat flow into the short at circuit end (test b), or into the $\lambda_{L/2}$ line (test d), by use of line section with low heat conduction, if necessary;
- for voltage test: prevent discharging within test arrangement (other than in specimen) by proper end preparation, if necessary use field effect electrodes.

NOTE - The wavelength must be considerably longer than the connector.

9.2.3 *Contact resistance, outer conductor and screen continuity also centre conductor continuity (mated cabled connectors)*

9.2.3.1 *General measuring requirements and procedure*

Measurements will in general be carried out with alternating current (a.c.). In case of dispute, however, the measurement with direct current shall govern. The frequency for a.c. measurements shall be 1 kHz ± 200 Hz.

The contact resistance shall normally be calculated from the potential difference measured between the points intended for the connection of the cables and the current. The contact shall be made before the current is switched on.

When direct access to the terminations is impractical, as in the case of mated cabled connectors required for environmental conditioning, a measurement of the centre conductor continuity shall be made.

The centre conductor continuity procedure may also be employed, with adaptation for measuring the outer conductor continuity of triaxial connectors fitted with triaxial cables. In this situation the connectors and the cable outer screens prevent direct access to the connector outer conductor.

In order to prevent the breakdown of possible insulating layers on the contacts, the electromotive force (e.m.f.) of the measuring circuit shall not exceed 20 mV (peak value for a.c.).

In order to prevent undue heating of the contacts, the current shall not exceed 100 mA or the value specified by the relevant specification.

The measuring set-up shall be such as to ensure that the result is within ±10 % of the resistance to be measured, unless another accuracy is given in the relevant specification.

In general the resistances of the centre contact R_c and the outer contact R_o of a pair of connectors shall be measured separately. The relevant specification shall state explicitly if the total resistance R_{tot} of the two contacts in series is to be determined by a direct measurement.

9.2.3.2 *Procedure*

The relevant value of the contact resistance is the mean value calculated from five consecutive measuring cycles. No individual value shall exceed twice the mean value.

One measuring cycle consists of:

when measuring with a.c.:

a) making the contact (engaging the connectors);
b) connection of voltage source;
c) measurement;
d) disconnection of voltage source;
e) breaking the contact (disengaging the connectors)

when measuring with d.c.:

a) making the contact (engaging the connectors);
b) connection of voltage source in one polarity;
c) measurement;
d) connection of voltage source in reverse polarity;
e) measurement;
f) disconnection of voltage source;
g) breaking the contact (disengaging the connectors).

9.2.3.3 *Requirements*

1) Contact resistance and outer conductor continuity

The values shall not exceed those specified by the relevant specification.

2) Centre conductor continuity, and outer conductor and screen continuity (mated cabled connectors)

The overall resistances of the mated connectors and their attached cables shall be measured between the free end of the cable conductors. The connectors shall not be disengaged between making the last measurement prior to the conditioning and the first measurement after conditioning.

The changes in resistance of the centre conductor, outer conductor and, when applicable, the screen of a mated pair of connectors inclusive of cable resistance, shall not deviate, after conditioning, by more than the appropriate maximum permitted values indicated in the relevant specification.

9.2.3.4 *Information to be given in the relevant specification*

a) upper limit of resistance for centre contact and outer conductor/screen continuity as appropriate;

b) the maximum percentage change of the initial total measured resistances of mated cabled connectors to be permitted after conditioning;

c) any deviation from standard procedure.

9.2.4 *Centre and outer conductor contact continuity under severe mechanical conditioning*

9.2.4.1 *Testing procedure*

The continuity of the centre and the outer contacts of a mated pair of connectors shall be tested during the vibration (see 9.3.3), the bump (9.3.13) and the shock test (9.3.14), as required by the relevant specification.

The test equipment, for instance an oscilloscope or an electronic apparatus with adequate display or permitting the counting of interruptions, shall have a resolution of better than 1 μs.

A current of at least 100 mA shall be flowing through each set of contacts. Contacts may be connected in series. Other values may be specified for the current in the relevant specification.

9.2.4.2 *Requirements*

There shall be no intermittences under the conditions specified by the relevant specification.

9.2.4.3 *Information to be given in the relevant specification*

See 9.3.3.2, 9.3.13.2, 9.3.14.2.

9.2.5 *Insulation resistance*

9.2.5.1 *Procedure*

The insulation resistance shall be measured between the contacts with a d.c. voltage of 500 V ± 50 V or with the rated voltage of the connector whichever is less.

The insulation resistance shall be measured after an electrification time of 1 min ±5 s.

NOTE - When appropriate, the reading may be taken after a shorter period.

9.2.5.2 *Requirements*

The value of the insulation resistance shall be not less than the value specified by the relevant specification.

9.2.5.3 *Information to be given in the relevant specification*

a) value of the test voltage if other than 500 V;

b) minimum value of insulation resistance;

c) any deviation from the standard test procedure.

9.2.6 *Voltage proof*

9.2.6.1 *Procedure and requirements*

Connectors shall withstand without breakdown or flashover with the voltage specified by the relevant specification.

An appropriate cable shall be attached to the connectors and the connectors shall be tested both mated and unmated.

An a.c. voltage at a frequency between 40 Hz and 65 Hz shall be applied for 60 s for qualification approval and for 5 s for quality conformance inspection unless otherwise prescribed in the relevant specification.

The relation between the rated voltage *U* and the test voltage *E* (r.m.s. values) is given by:

$E = 3\ U$ for connectors having a rated voltage up to and including 1 kV and

$E = 1{,}5\ U$, with a minimum of 3 kV, for connectors having a rated voltage exceeding 1 kV.

9.2.6.2 *Information to be given in the relevant specification*

a) value of the test voltage;

b) any deviation from the standard test procedure.

9.2.7 *Water immersion test*

9.2.7.1 *Procedure and requirements*

Suitably mated connectors fitted with mating face seals and attached to appropriate cables shall be submerged in tap water at 70 °C ± 2 °C to a depth of 30 cm.

After 1 h the water shall be allowed to cool to room temperature and shall be held at this temperature for 1 h. The water shall then be cooled to 10 °C ± 2 °C in approximately 1 h and then kept at this temperature for 1 h.

The water shall then be allowed to warm up to room temperature. The connectors shall remain under water until 24 h have elapsed from the time of starting the test. Whilst still submerged, the following test and measurement shall be carried out as required by the relevant specification:

a) Voltage proof

An a.c. voltage as specified in the relevant specification shall be applied at a frequency between 40 Hz and 65 Hz between the inner contact and the body of the connector for a period of 1 min. There shall be no breakdown or flashover.

b) Insulation resistance

The insulation resistance shall be measured in accordance with 9.2.5.

9.2.7.2 *Information to be given in the relevant specification*

a) value of the test voltage;

b) any deviation from the standard test procedure.

9.2.8 *Screening effectiveness*

9.2.8.1 *General considerations*

Screening effectiveness in the context of radio-frequency coaxial transmission lines is the ability of the outer conductor to protect the transmission line from being disturbed by outside electromagnetic fields, and vice-versa. With respect to r.f. coaxial connectors a longitudinal current flowing on the outer shell should not cause an undue voltage in the coaxial circuit.

The quotient of the transferred electromotive force, or the equivalent voltage U_t, by the outside longitudinal current I_l: $\frac{U_t}{I_l} = Z_t$ is called "the transfer impedance" and is generally an adequate quantity for defining the screening effectiveness of r.f. coaxial connectors.

A connector assembly with properly mounted cables or lines has three major possible leakage areas: the region around the mating face, the coupling device and the two cable entries. Since in IEC 169 only mating face and locking (coupling) mechanisms are standardized, the primary interest concerns the screening effectiveness of this part of the connector assembly. This does not, however, exclude that the measuring methods may also be used either for determining the transfer impedance at any individual spots of leakage if due care is taken to eliminate coupling contributions from the other leakages, or for total transfer impedance. In the latter case, and especially at high frequencies, the occurrence of directional effects has to be taken into account.

It shall be emphasized that the transfer impedance of r.f. connectors, and thus the screening effectiveness, has by no means a stable, fixed value applicable to each particular specimen or pair. In particular, Z_t is mostly much dependent on mechanical and contact circumstances. For instance, the value may be considerably lowered by stronger tightening of the coupling nut. Moreover, the exact value normally cannot be reproduced.

A fresh connector pair in general shows a reduction of Z_t with repeated disengagement and re-engagement, but the value may increase again after some dozens of cycles, perhaps due to wear and tear. Very little is also yet known on the behaviour during use and ageing of connectors.

For radio-frequency applications, the transfer impedance Z_t shall be expressed as a function of frequency and, in general, be measured in the frequency domain. While at higher frequencies no other practicable measuring method is known, at frequencies up to a few hundred megahertz time domain measurement with pulse technique may be used, with, if appropriate, subsequent transformation of the result into the frequency domain.

In order to measure the screening effectiveness of the mating part of a connector pair, suitable cables are attached to the connectors in such a way as to exclude any leakage at the cable entries. For frequencies above 10 MHz, semi-rigid cables or solid tubular outer conductors are generally preferred.

Below 10 MHz, cables with low leakage at low frequencies should be selected. The standardized test procedure in the frequency domain does not permit the inclusion of a fixing-flange style of connector as one-half of the connector pair to be tested, unless the flange is first removed.

The time domain pulse method is described in 9.2.8.3. It may be particularly useful in lower frequency bands up to a few hundred megahertz. If the appropriate test equipment (pulse generator combined with cathode ray oscilloscope) is readily available the test may be carried out very quickly, and, provided adequate precautions are being taken, with nearly the same sensitivity as in the frequency domain test. It has, further, the advantage that leakage spots may be identified in case of multiple leakages.

Various test methods may be used for the measurement of the transfer impedance in the frequency domain and in the time domain pulse method. In case of dispute, however, the method standardized in the following 9.2.8.2, using a tri-coaxial test set-up (or a set-up where the outer exciting line is formed by waveguides) shall govern as reference test method.

NOTE - As a guiding rule the tri-coaxial set-up may be used to approximately one-third of the upper frequency limit of the connector type to be tested, without the risk of disturbance by overmodes in the outer line. At higher frequencies the waveguide set-up should be applied, in which case the limit lies at about three-quarters of the connector limit. Experience shows that at these high frequencies the transfer impedance no longer varies appreciably with frequency.

For type testing, measurements shall always be carried out at the first engagement on a number of pairs of fresh connectors. It is not recommended that a standard test connector should be coupled to the specimen under test with the intention of attributing measured screening deficiencies to the specimen under test.

The relevant specification shall state the number of pairs to be measured, the tightening torque for the coupling nut and, where relevant, the frequency range.

9.2.8.2 *Measurement in the frequency domain*

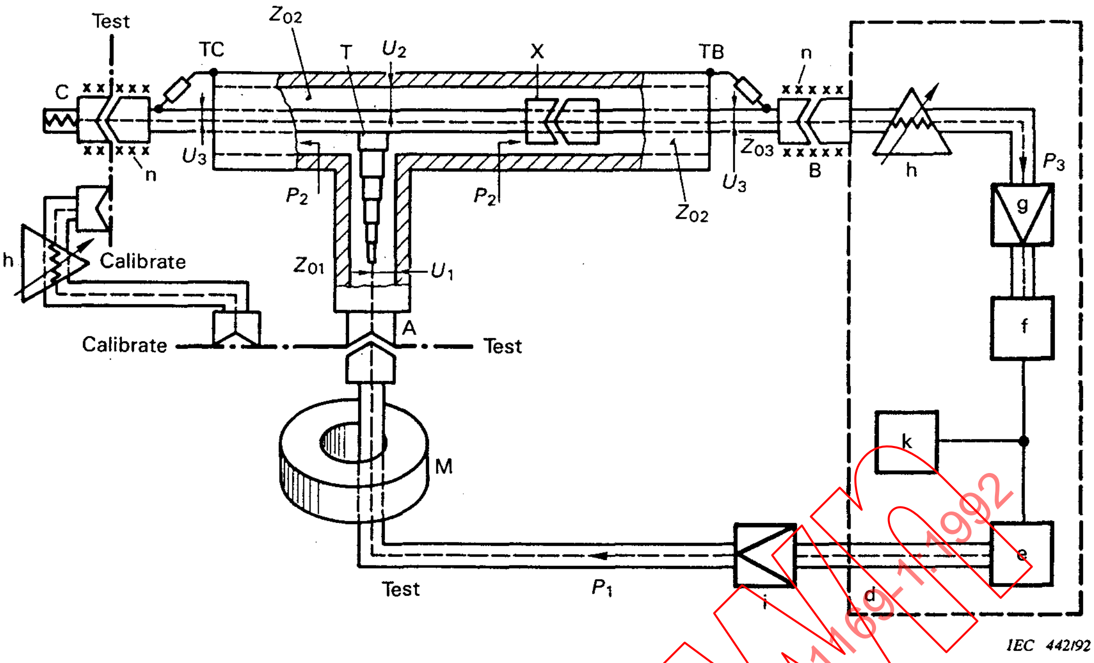
9.2.8.2.1 *Principle of the matched tri-coaxial test set-up*

The principle of the matched tri-coaxial test set-up is shown in figure 15, and explained as follows:

In this tri-coaxial set-up, both the inner and the outer coaxial systems are matched at their far ends, that is terminated by the characteristic impedance of the line, in order to avoid, or at least to minimize, the formation of standing waves. The outer system is fed at port A through a lateral arm, containing a matching transformer, to a T-junction acting as a power divider.

The multistep transformer serves to adapt the impedance ½ Z_{02} at the T-junction to the impedance Z_{01} of the feeding line in the frequency range of 1 GHz to 10 GHz. The transformer becomes less effective at lower frequencies. The resultant mismatch is, however, tolerable. Assuming the source impedance to be invariably equal to Z_{01}, calculation shows that the error introduced amounts to 0,5 dB only. This is small compared to the unavoidable measuring uncertainty and in particular the high dispersion of Z_t values themselves. The advantage, on the other hand, is to have only one mechanical feeding arrangement with the convenience of the same formula for calculating Z_t through the whole frequency range*.

* It could be argued that for the same reasons the multistep transformer might also be superfluous in the frequency range from 1 GHz to 10 GHz. However, at such high frequencies good matching proves even more critical in avoiding losses.



A	Power feed connection	e	Tracking generator or synthesized signal generator
B, C	Measuring ports	f	Spectrum analyzer
X	Connector pair under test	g	Low noise preamplifier
TB, TC	Outer system terminating devices with impedance Z_{02}	h	Calibrated variable attenuators
T	Matched power dividing T-junction	i	Power amplifier (if needed)
M	Ferrite rings	k	Bus controller
d	Screened room	n	Additional screening copper braid

Figure 15 – Principle of the matched tri-coaxial test set-up (optimized condition for the frequency range 1 GHz to 10 GHz)

At the T junction, reactance correcting stubs, not shown in figure 15 but depicted in figure 19, are necessary.

The signal voltages U_3 at ports B and C of the inner line, caused by the injected voltage U_t, are alternately measured both at B and C. Incidentally their equality is a criterion for the symmetry of the system and the absence of directional effects.

For calibration of the set-up the input signal is fed with the aid of a separate branch of coaxial line, comprising a variable attenuator, to the port opposite to the measuring port (to C if U_3 is measured at B). This implies the equality $Z_{03} = Z_{01}$.

The quantitative relationships below make use of two approximations which, however, are fully justified, bearing in mind the practical accuracy needed: The transfer impedance Z_t is very small and thus negligible in comparison to Z_{02} et Z_{03}; further, the attenuation and losses in the coaxial lines and the multistep transformer are neglected.

The transferred voltage U_t results in two voltages U_3 of equal amplitude at the ports B and C:

$$U_3 = \frac{1}{2} U_t. \quad \text{Since } U_t = Z_t \cdot I_2, \quad U_3 = \frac{1}{2} Z_t \cdot I_2 \qquad (1)$$

The junction T acts as a lossless power divider and, since the multistep of the transformer is considered to be ideal, it follows:

$$P_2 = \frac{1}{2} P_1$$

Because: $P_1 = \frac{U_1^2}{Z_{01}}$, $P_2 = \frac{U_2^2}{Z_{02}}$; $\frac{U_2^2}{Z_{02}} = \frac{1}{2} \frac{U_1^2}{Z_{01}}$, thus $U_2 = U_1 \sqrt{\frac{1}{2} \frac{Z_{02}}{Z_{01}}}$

considering further that: $I_2 = \frac{U_1}{Z_{02}}$; $I_2 = \frac{U_1}{\sqrt{2 Z_{01} \cdot Z_{02}}}$ (2)

combining equations (1) and (2):

$$U_3 = \frac{1}{2} \cdot Z_t \frac{U_1}{\sqrt{2 Z_{01} \cdot Z_{02}}} ; \quad Z_t = 2\sqrt{2} \sqrt{Z_{01} \cdot Z_{02}} \frac{U_3}{U_1}$$

Z_{02} might be chosen arbitrarily, the transformer being given the correct matching ratio. However, in general the adequate solution is to have $Z_{01} = Z_{02} = Z_0$.

This results in: $Z_t = 2\sqrt{2} \frac{U_3}{U_1} Z_0 = 2\sqrt{2} \sqrt{\frac{P_3}{P_1}} \cdot Z_0$

The measuring instrumentation consists of a tracking generator or synthesized signal generator followed by a power amplifier (if needed) on the feeding side; on the receiver side an input variable attenuator, a low noise preamplifier and a spectrum analyzer. A quick procedure is possible with computer controlled automatic driving (step by step) of the generator and the spectrum analyzer. When calibrating the system, sharing of the total attenuation between two attenuators allows an optimum compromise with regard to random noise and residual stray coupling to be achieved. The port at C of course to be correctly terminated and both ports at B and C in general need additional shielding with copper braid.

At high screening effectiveness and for best performance it is recommended to use a screened room (Faraday cage) as indicated in figure 15.

It is essential that the test set-up be checked for its limit capabilities by substituting the connector pair under test with a completely solid metal shell (for instance a copper tube) of the same outer dimensions as the connectors.

9.2.8.2.2 *Practical construction of the matched tri-coaxial set-up for the frequency range from 1 kHz to 10 GHz*

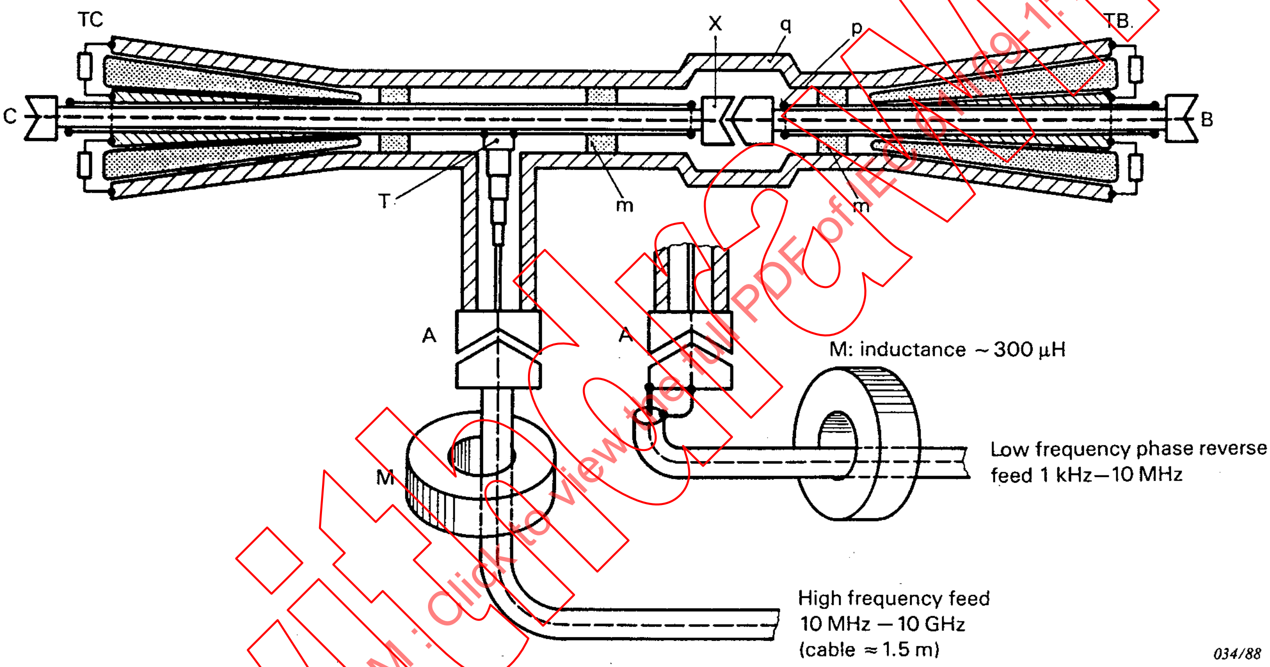
For the practical construction of the test set-up, a few items need more detailed specifications than are given in 9.2.8.2.1 and in figure 15.

Figure 16, shows, besides other particularities of the tri-coaxial set-up, the procedures for feeding the input power in the two frequency ranges; from 10 MHz to 10 GHz and from 1 kHz to 10 MHz.

Above 10 MHz the feeding is quite normal and it is only necessary to take care of the feeding cable, which should have an approximate length of 1,5 m, in order to provide a sufficient impedance (mainly reactance) to the normally open "earth loop" (see figure 15, at the input the earth is on the outer conductor, whereas at the measuring port the earth of the screened room is connected with the middle tube at B). The inductance of the loop may be increased, if required, by ferrite rings, as shown in figures 15 and 16.

For frequencies below approximately 10 MHz down to 1 kHz, experience has shown that correct results are obtained by feeding with reversed polarity, as depicted in figure 16. Ferrite rings may be necessary for decoupling, particularly towards the upper frequency region of the range.

The multistep matching transformer requires lengthy calculations to determine its dimensions. The data for a practical design are given in figure 17.



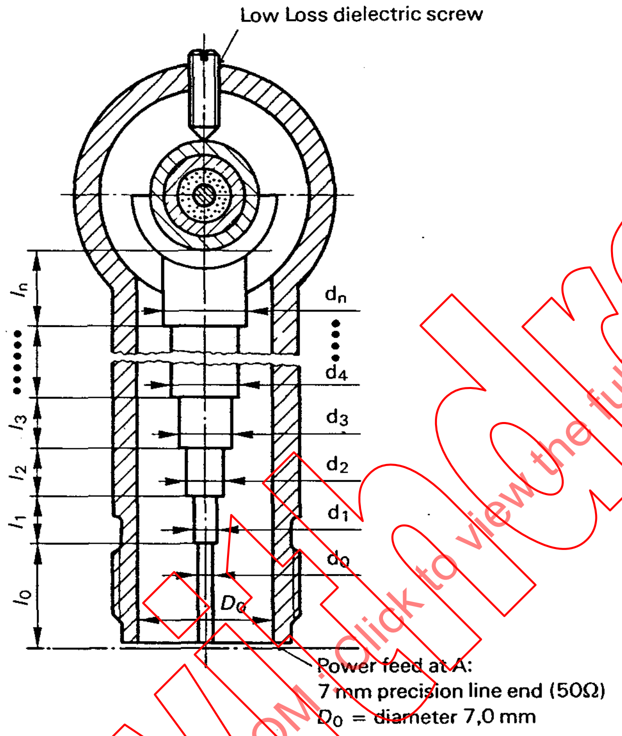
A	Power feed connection	M	Ferrite rings
B	Measuring port (forward screening effectiveness)	m	Foam dielectric beads
C	Measuring port (backward screening effectiveness)	p	Solder junction between brass tubes and coaxial cable or line
X	Connector pair under test	q	Bulge for measurement of larger connectors
TB, TC	Outer system terminating devices (detail figure 18)		
T	Matched power dividing T-junction (detail figure 17)		

Figure 16 – Practical tri-coaxial test set-up for the two frequency ranges: 1 kHz to 10 MHz and 10 MHz to ~ 10 GHz

An important detail is the construction of the terminations TB and TC, which are to cover the whole frequency range from 1 kHz to 10 GHz; see also figure 18. At frequencies up to about 1 GHz, each termination consists of four parallel resistors of 200 Ω (assuming Z_{02} = 50 Ω). At higher frequencies, up to 10 GHz, the wave energy is dissipated in the tunnel-shaped expansions (horns) filled with absorbing conical elements.

In comparison with figure 15, figure 16 shows also additional brass tubes, (p), 4 mm to 6 mm in diameter, surrounding the semi-rigid cables and soldered to them near their mounting to the connector pair under test.

The outer conductor of the outer system has an inner diameter of 14 mm. Thus, SMA, APC-3,5 and similar sized connectors can be measured without the necessity of increasing this diameter in the region of the connector pair. The brass tubes surrounding the semi-rigid cables have about the same outer diameter as the SMA connector shell and maintain therefore the condition of constant characteristic impedance Z_{02} = 50 Ω. For the measurement of larger size connectors, APC-7 or N-types for example, the dimension of the outer coaxial tube has to be increased over approximately the length of the connector pair, forming a bulge *q*, as seen in figure 16. The dimensions are not critical; reflection factors up to about 0,5 are acceptable (mismatch loss less than 1,2 dB).



steps n	l [mm]	Ø d [mm]
0	9,16	3,04
1	12,07	3,08
2	11,40	3,17
3	10,93	3,26
4	10,17	3,34
5	7,55	3,42
6	6,08	3,50
7	6,37	3,58
8	6,84	3,66
9	5,53	3,74
10	5,98	3,82
11	5,98	3,90
12	5,53	3,98
13	6,84	4,05
14	6,37	4,13
15	6,08	4,20
16	7,55	4,27
17	10,17	4,34
18	10,93	4,41
19	11,40	4,48
22	12,07	4,55
n = 23	10,00	4,58

035/88

Figure 17 – Multistep impedance transformer for T-junction, effective in the frequency range from 1 GHz to 10 GHz

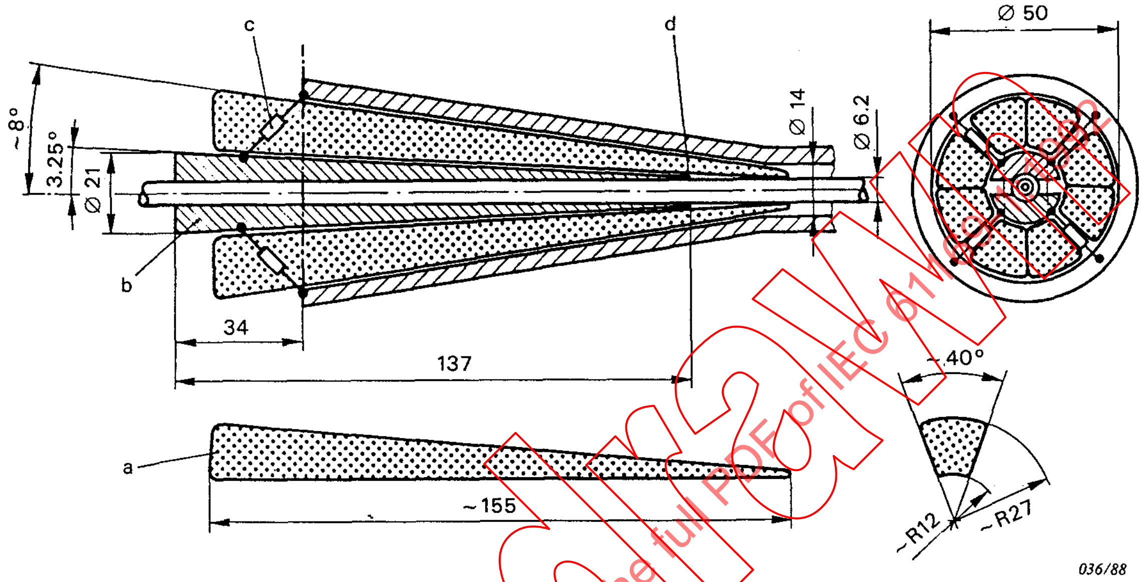
An example of the mechanical construction for the set-up according to figure 16, is depicted in figure 17. As an important detail this figure also shows the matching elements, e, at the feeding junction T (see figure 19).

9.2.8.2.3 *The matched waveguide assembly for the frequency range from 3 GHz to 18 GHz*

For a further extension of the frequency range beyond the capabilities of the matched tri-coaxial set-up, a relatively simple waveguide assembly has been produced which allows measurements up to about ¾ of the connector's upper frequency limit. According to figure 20, it consists of two waveguides running side by side and having a common broadside wall.

This wall has a longitudinal slot and a broader opening into which the connector pair with mounted semi-rigid cables fit.

The input signal is split by a 3 dB in-phase power divider and then launched in phase opposition into the two waveguide arms, these waveguides being terminated by a matched load at the opposite ends. If the assembly is symmetrical the field around the connector pair under test is quite similar to the TEM mode in a coaxial arrangement. The quasi TEM mode impedance Z_{02} of the outer system at the connector pair depends on the connector and the waveguide dimensions and may vary from $\frac{Z_{03}}{3}$ to $3 \cdot Z_{03}$; but this affects the overall accuracy even less than the wide dispersion of practically measured screening values, as occurring with repeated engaging and separation of the connectors under test.



a = Low loss dielectric foam cones, coated with one layer of an absorbing mixture of for example 17 g resin polymer (semi-flexible type) and 68 g iron powder (brush painted).

b = The inner conductor cone is mechanically screwed together to assure good contact pressure at the area d. The whole cone is longitudinally adjustable on the inner coaxial system to allow the overall reflection factor to be optimized from d.c. to the upper frequency limit of about 10 GHz (this must be measured at the feeding point A, figure 15, through the whole assembly).

c = Four low power r.f. resistors 200 Ω.

Figure 18 – Low and high frequency combining feed through terminations TB, TC frequency range d.c. to ~ 10 GHz

Assuming that the power divider and the launching devices do not cause losses, the total power P_2 flowing along the connector pair is equal to the input power P_1. Therefore, and assuming that $Z_{02} = Z_{03} = Z_0$, the relation for Z_t is:

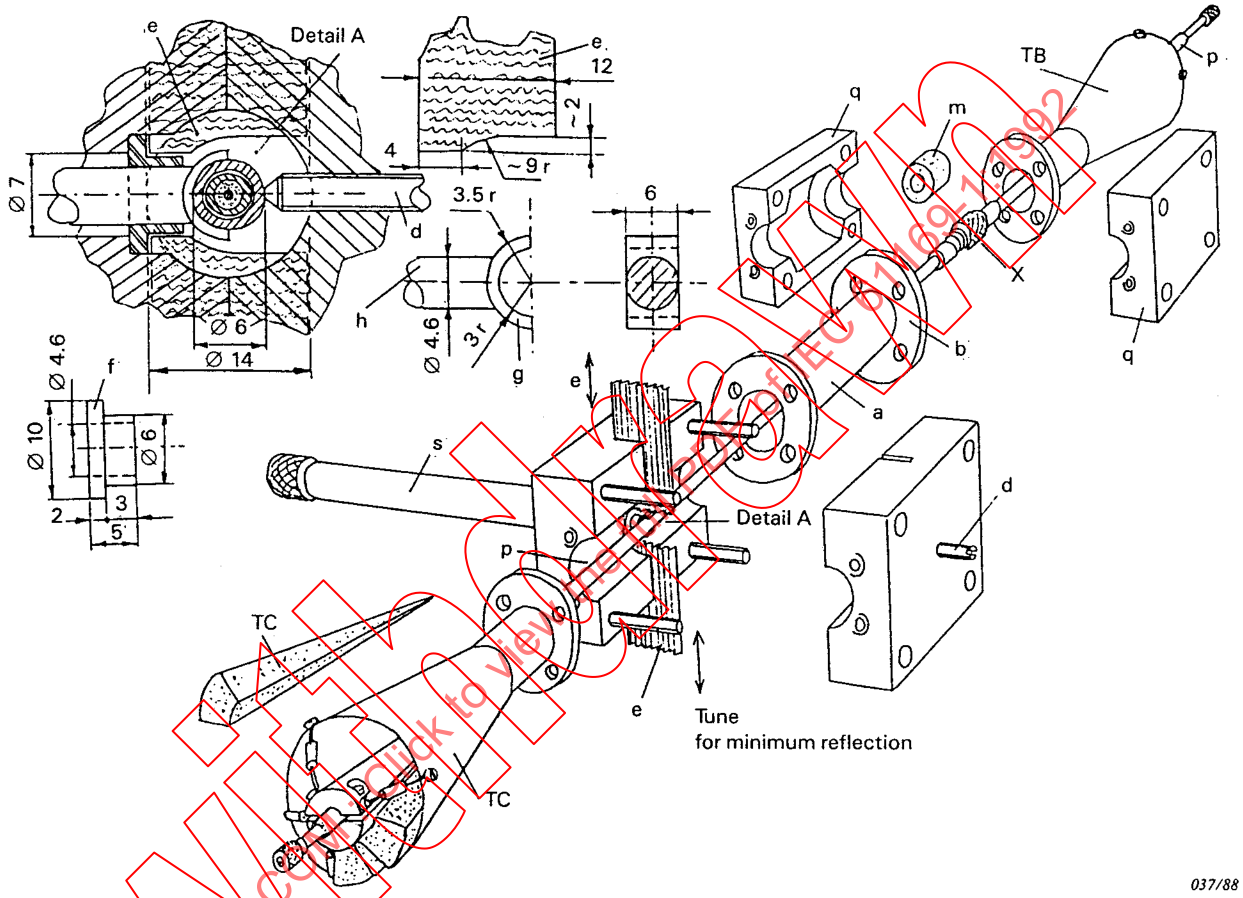
$$Z_t = 2 \cdot \frac{U_3}{U_1} Z_0 = 2 \sqrt{\frac{P_3}{P_1}} Z_0$$

The entire measuring set-up is exactly the same as for the tri-coaxial arrangement and all information given there applies as well.

Comparison of results obtained in the overlapping frequency range of the tri-coaxial set-up and the waveguide assembly on a dummy with fixed and stable transfer impedance in place of a connector pair has proved agreement within 4 dB.

Figure 21, is an exploded view of the waveguide assembly. The residual leakage and the mismatch of the set-up can be tested before cutting the openings in the two thin sheets c. These apertures are cut with a knife such that there is a 1 mm spacing between the sheet edge d and the connector body X, thus enabling the longitudinal current to flow on the surfaces of the bodies of the connector pair.

In the zone of the connector pair under test, each waveguide of the assembly works more or less similarly to a ridge guide (see right side of figure 20), with the maximum of magnetic field and current on the surfaces of the connector pair.

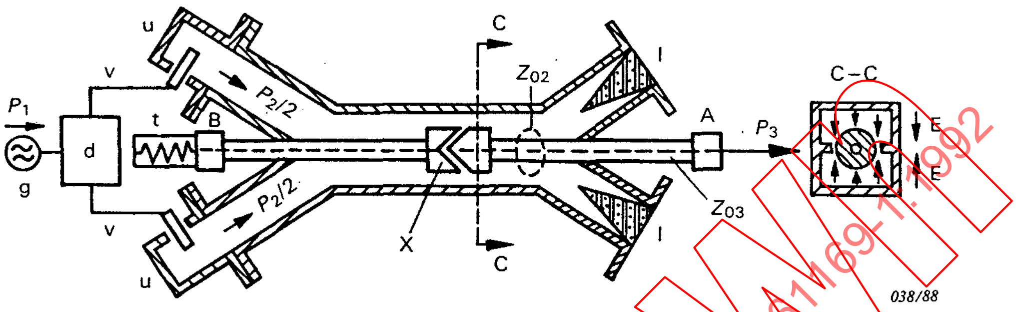


a	Outer conductor of outer system with inner diameter of 14 mm
b	Mounting flanges
d	Dielectric fixing screw to assure contact pressure at T-junction
e	T-junction adjusting matching stubs
f	Axial fixing and centering solid low loss dielectric bead
g	T-contact fork
h	Inner conductor of multistep transformer, low impedance side
m	Several centering low loss foam dielectric beads
p	Solid brass tube of outer diameter of 6 mm surrounding semi-rigid cable
q	Bulge in outer conductor for large connectors (size dependent)
s	Outer conductor of feeding multistep transformer with inner diameter of 7 mm
TB, TC	Conical terminations with absorbing layer coated foam segments and four resistors (200 Ω each in parallel)
X	Connector pair under test

Figure 19 – Example of a mechanical construction for the set-up according to figure 16

The dimensions of the trapezoidal openings in the two metal plates b depend on the waveguide and connector sizes and are expressed as fractions of the connector, cable and waveguide dimensions (see figure 17). The wave-guide assembly has to be mechanically fixed by clamps and the connector pair and cable set-up shall also be fastened to assure stable measuring conditions.

The admissible range of the outer diameter of the connector pair under test is approximately (0,25 ... 0,9) · a.



A	Measuring port	Z_{03}	$Z_{03} = Z_0$. Impedance of inner system
B, t	Termination at opposite port	Z_{02}	Quasi TEM impedance of outer system
X	Connector pair under test		
E	Electrical field in test area	P_1	Input power
d	In-phase power divider	P_2	Total power in outer system (both wave-guides together)
g	Generator		
l	Matched waveguide load	P_3	Power delivered to terminations of system 3 (inner system)
u	Coaxial to waveguide transition		
v	Semi-rigid coaxial cables with equal electrical lengths		

Figure 20 – Waveguide set-up

9.2.8.2.4 *Practical limits of measurable attenuation range and reproducibility*

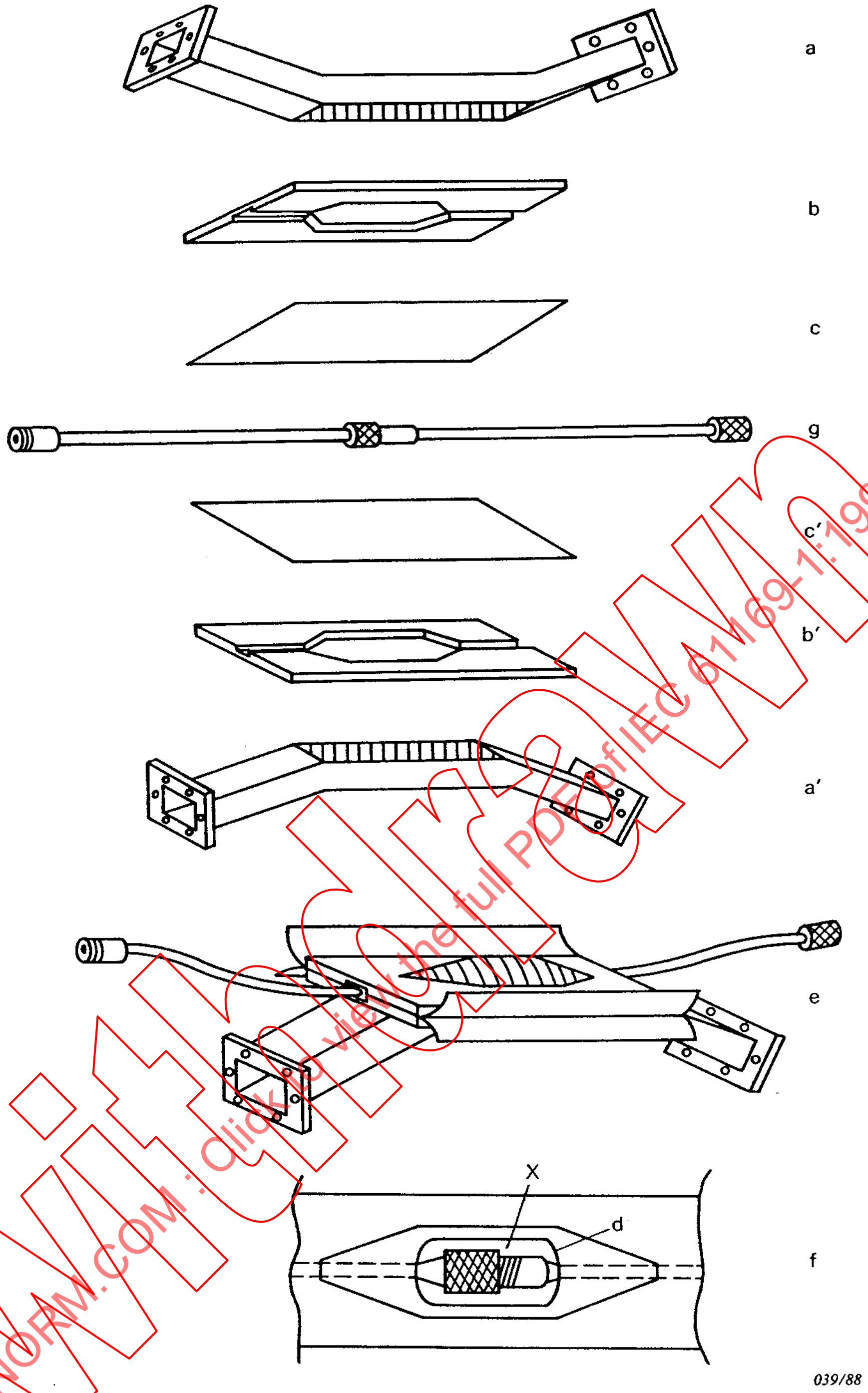
In practice the lowest value of Z_t measurable by swept methods depends on the characteristics of the low noise preamplifier, the power amplifier and the spectrum analyzer.

It may be expressed by the lowest ratio $\frac{P_3}{P_2}$ obtainable with adequate accuracy, where P_3 is the power delivered at each termination of the inner coaxial system, and P_2 the wave power flowing over the test connector pair in the outer system, the characteristic impedance being all of equal value Z_0.

According to the derivation given earlier the relation between Z_t and $\frac{P_3}{P_2}$ is:

$$Z_t = 2\ \frac{U_3}{U_2}\ Z_0 = 2\sqrt{\frac{P_3}{P_2}} \cdot Z_0$$

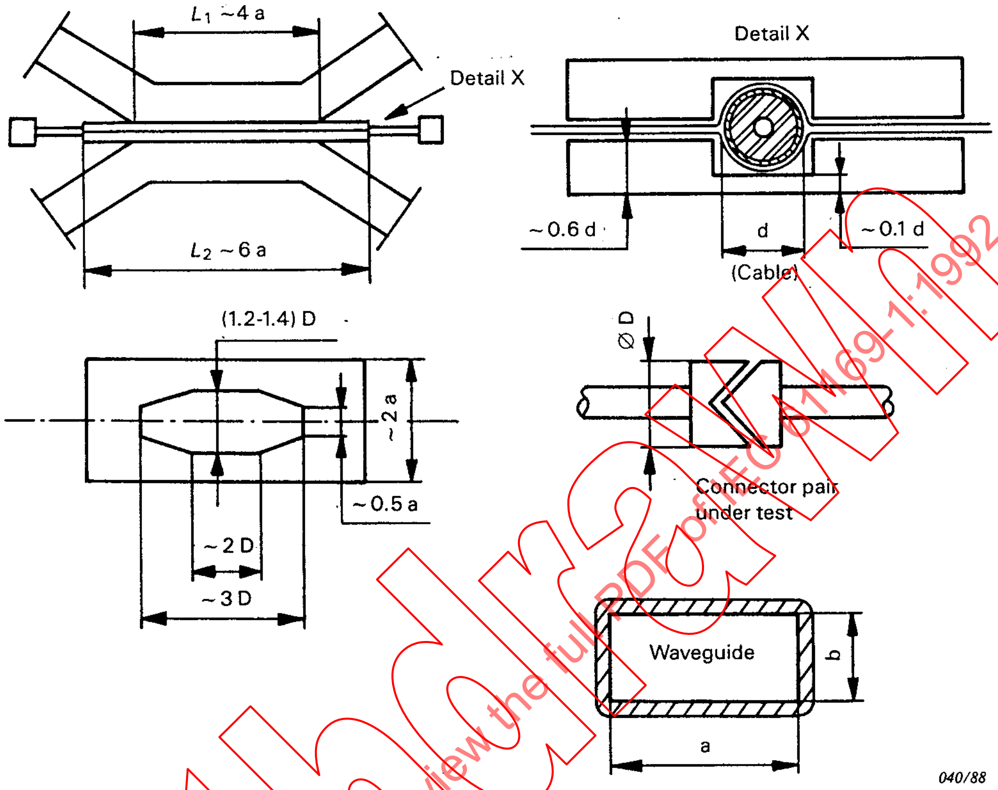
The practical limit, $\frac{P_3}{P_2}$ expressed in decibels, in the whole frequency 1 kHz to 12 GHz, obtainable with the usual equipment, is about 155 dB. This corresponds to $Z_t \approx 2\ \mu\Omega$.



a, a'	Upper and lower waveguides	e	Completed assembly (upper waveguide removed), thin sheets not yet cut, ready for leakage and mismatch test
b, b'	Upper and lower diaphragm plates	f	View of diaphragm within assembly
c,c'	Upper and lower thin sheets of ≈ 0,05 mm thickness	d	Edge of thin sheet
g	Connector pair under test with mounted semi-rigid cables and terminating connectors	X	Connector pair under test

Figure 21 – Exploded view of waveguide assembly

The measuring accuracy depends on the quality of the calibrated attenuator, the instrument stability and the (unwanted) reflections at several spots of the set-up. It is found to be about ±3 dB. This seems to be adequate when considering the much wider dispersion of attenuation values resulting from problems such as the mechanical handling of the connector pairs. For instance, doubling the coupling torque when engaging an N-type connector pair may easily lower Z_t by 30 dB and more.



a, b Inner sizes of waveguides
d Outer diameter of cable

Figure 22 – Waveguide assembly dimensions

9.2.8.3 *Measurement in the time domain*

Under consideration.

9.2.9 *Discharge test (corona test)*

9.2.9.1 *Procedure and requirements*

For this test, an appropriate cable shall be attached to the connector and the test voltage shall be applied between the conductors of the cable. No grease or similar compounds shall be used in or on the test sample.

The application of a high voltage to the test samples immediately before the discharge test, may affect the measured results; a rest interval is therefore recommended, after previous voltage application, before carrying out the discharge test.

Care shall be taken to avoid spurious effects caused by corona at the cable ends.

The connectors shall be tested only in the mated condition.

The voltage to be applied shall have a frequency between 40 Hz and 60 Hz. The total duration of the application of the voltage shall not exceed 5 min.

The circuit for this test shall be as shown in figure 23, or a circuit giving the same results.

To allow the measurement of the discharges, the components of the test circuit shall be corona free to the extent that discharges of 5 pC or more occurring in the test specimen are not obscured. The parts submerged in oil shall be purged of air.

The voltage shall be slowly increased until the detector, operated at a sensitivity of 5 pC, indicates a sustained corona discharge. Then the voltage shall immediately be decreased until corona is at the 5 pC level, the corresponding voltage being the corona level of the connector under test.

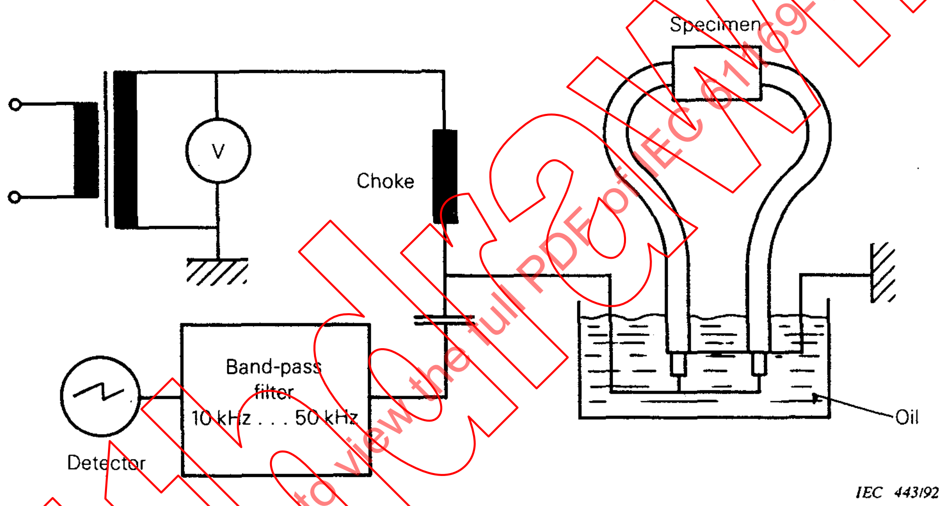


Figure 23 – Measuring circuit for the discharge test

The test may be carried out at reduced atmospheric pressure when required by the relevant specification to simulate high altitude applications.

9.2.9.2 *Information to be given in the relevant specification*

a) minimum value of the extinction voltage;

b) atmospheric pressure if other than standard;

c) any deviation from the standard test procedure.

9.3 *Mechanical tests and measuring procedures*

9.3.1 *General*

Measurements to be made at any stage of these tests shall be indicated in the relevant specification.

9.3.2 *Soldering, vibration, gauge retention force, effectiveness of contact captivation*

NOTE - These tests formed a "standard testing sequence" in IEC 169-1 but are now to be considered as individual tests. The test called "static load" has been deleted.

9.3.2.1 *Soldering*

Terminations and surfaces to which soldered connections are to be made shall be tested to ensure that the surfaces wet easily and that damage does not occur due to the heating effect of the soldering processes. Tests shall be carried out in accordance with Test Ta of IEC 68-2-20, and when required the relevant specification shall identify the termination(s) and provide the information as indicated for Test Ta. Test Tb may be applied if specified in the relevant specification.

9.3.2.1.1 *Solderability*

Tests shall be made in accordance with Test Ta of IEC 68-2-20. This test may be carried out on piece-parts/sub-assemblies taken from batches prior to assembly into connectors and, if prescribed, subject to prior conditioning or ageing.

When applied to assembled connectors the requirements shall be laid down in the relevant specification which shall also prescribe:

– soldering iron method – the size of the bit;
– solder bath - the depth of the immersion.

NOTE - For soldering bodies alternative procedures may be required. These shall be as prescribed in the relevant specification.

Solderability of printed board mounting connectors may be tested in accordance with Test Ta of IEC 68-2-54 using the wetting balance method. This method may also be used as a reference method for terminations irrespective of shape. When requiring use of this method, the appropriate parameters of one or more of the following requirements shall be given in the relevant specification:

i) for the onset of wetting;
ii) for the progress of wetting;
iii) for the stability of the wetting.

9.3.2.1.2 *Resistance to soldering heat*

This test shall be carried out on assembled connectors in the unmated condition. They shall be subjected to Method 1B or Method 2 of IEC 68-2-20 which includes details of the normal requirements and the information to be given in the relevant specification.

NOTE - For soldering bodies alternative procedures may be required. These shall be as prescribed in the relevant specification.

9.3.3 *Vibration*

9.3.3.1 *Procedure*

The test shall be carried out on mated sets of connectors in accordance with Test Fc of IEC 68-2-6. Unless otherwise specified, the test shall consist of endurance by sweeping only.

The vibration severity shall be defined by the combination of three parameters: frequency range, vibration amplitude and duration of endurance. The relevant specification shall prescribe the appropriate requirement for each parameter selected from the following preferred values:

Swept frequency ranges – 10 Hz – 150 Hz
10 Hz – 500 Hz
10 Hz – 2 000 Hz

Vibration amplitude (with cross-over frequency 57 Hz – 62 Hz)

Peak displacement (not peak-to-peak) amplitude below cross-over frequency	Acceleration amplitude above cross-over frequency	
mm	m/s²	gn
0,75 1,0 1,5	100 150 200	10 15 20

Duration of endurance – 2, 5, 12 or 20 sweep cycles (in each axis)

The connectors shall be vibrated in each of three perpendicular directions, one of which shall be parallel to the common axis of the connectors.

The centre and the outer contact continuity shall be monitored as specified in 9.2.4.

9.3.3.2 *Information to be given in the relevant specification*

a) appropriate cable to be used, details of mounting connectors and clamping of cables if other than in 9.1.1;

b) severities;

c) performance requirements;

d) any deviation from the standard test procedure.

9.3.4 *Gauge retention force (resilient contacts)*

9.3.4.1 *Procedure and requirements*

Resilient contacts, either female (socket) or male (pin), shall be tested in the following manner using the specified gauges:

a) The gauge causing the maximum deformation shall be applied to the contact and withdrawn three times. For a centre female contact, the diameter of the gauge shall be the maximum specified diameter of the mating male contact. For the outer male contact, the inner diameter of the gauge shall be the minimum specified diameter of the female body.

NOTE - The use of an oversize test gauge may be called for in the relevant specification.

b) The gauge causing minimum deformation shall then be engaged with the contact. The contact shall support the gauge when the gauge is hanging from the contact in the vertical position. For a centre female contact, the diameter of the gauge shall be the minimum specified diameter of the mating male contact. For an outer male contact, the inner diameter of the gauge shall be the maximum specified diameter of the female body.

9.3.4.2 *Information to be given in the relevant specification*

a) dimensional details of the gauge(s) for pre-conditioning;

b) dimensional details and mass of the gauge(s) for checking the retention force;

c) when required the insertion force of the pre-conditioning gauge(s);

d) any deviation from the standard test procedure.

9.3.5 *Centre contact captivation*

9.3.5.1 *Procedure*

Free connectors shall be fitted with an appropriate cable and fixed connectors with a wire.

An axial torque and/or force, as specified by the relevant specification, shall be applied smoothly to the centre contact. The relevant specification shall also prescribe the magnitude, the duration and the sense of application of torque and/or force.

9.3.5.2 *Requirements*

After removal of the stress, the permanent displacement of the centre contact with regard to the connector body shall not exceed the value specified in the relevant specification.

9.3.5.3 *Information to be given in the relevant specification*

a) appropriate cable to be used;

b) magnitude, duration and sense of torque and force;

c) any deviation from standard procedure and requirements.

9.3.6 *Engagement and separation forces and torques*

9.3.6.1 *General*

Engagement is the action of fully inserting the connector and operating the coupling mechanism, if any. Separation is the reverse procedure. Engagement and separation involve axial movements requiring insertion and withdrawal forces. Operation of the coupling mechanism may involve additional rotary movement of a coupling ring requiring a torque.

NOTE - Connectors with threaded coupling nuts are covered by 9.3.11.

9.3.6.2 *Procedure*

The test shall be carried out on connector pairs or with a gauge if specified by the relevant specification. There shall be five successive cycles of engagement and separation on the same test specimens. The forces and torques as applicable shall be measured on the fifth cycle.

9.3.6.3 *Requirement*

The insertion force and the coupling torque shall not exceed the value specified by the relevant specification. The momentary maximum decoupling torque and withdrawal force shall be within the limits specified by the relevant specification.

9.3.6.4 *Information to be given in the relevant specification*

a) maximum value of insertion force and coupling torque, where applicable;

b) momentary maximum and minimum values permitted for the decoupling torque, where applicable, and the withdrawal force;

c) any deviation from the standard procedure.

9.3.7 *Mechanical tests on cable fixing*

9.3.7.1 *Object*

To determine whether the device for fixing or clamping the cable is effective when tensile forces and/or torques are applied to the attached cable.

9.3.7.2 *Effect of cable rotation (nutation of cable end)*

9.3.7.3 *Procedure*

The cable as specified in the relevant specification shall be attached to the connector according to the manufacturer's instructions.

The length of the cable shall be equal to three times the specified minimum cable bending radius.

The connector shall be held in a convenient way and the free end of the cable deflected to such an amount that the minimum bending radius will be obtained. Holding this deflection constant, the cable end shall then be moved along a circle in a plane perpendicular to the axis of the connector for a prescribed number of revolutions (nutations). During this procedure, the cable shall not rotate within the attachment to the connector.

Unless otherwise specified the number of rotations shall be 10 in each direction.

9.3.7.4 *Requirements*

After the test, the cable shall not show any sign of deterioration due to rubbing.

9.3.7.5 *Information to be given in the relevant specification*

a) necessary characteristics of the appropriate cable;

b) minimum bending radius of the cable;

c) number of revolutions (nutations) in each direction if other than 10;

d) any deviation from the standard test method.

9.3.8 *Effectiveness of clamping device against cable pulling*

9.3.8.1 *Procedure*

The cable as specified in the relevant specification shall be attached to the connector(s) in accordance with the manufacturer's instructions. Unless otherwise specified the cable length shall be 100 mm to 150 mm. The connector shall be suitably fixed.

A tensile force as specified by the relevant specification shall be applied to the free end of the cable. If connectors are fitted to both ends of the cable the force shall be applied between the two connectors along the common axis of the cable and cable outlets. Unless otherwise specified the force shall be applied for a period of 60 s minimum and, in the case of a single connector, at a distance of at least 50 mm minimum from the cable outlet.

If explicitly specified, the reflection factor shall be measured.

9.3.8.2 *Requirements*

Neither the dielectric nor the sheath shall have moved in relation to the cable outlet of the connector(s).

If specified, the reflection factor shall not exceed the prescribed value.

9.3.8.3 *Information to be given in the relevant specification*

a) cable to be used and the length if other than 100 mm to 150 mm;

b) value of force, method of application and its point of application if other than 50 mm minimum from cable outlet;

c) duration of application of force if other than 60 s minimum;

d) requirements for the reflection factor, if applicable;

e) any deviation from the standard test procedure.

9.3.9 *Effectiveness of clamping device against cable bending*

9.3.9.1 *Procedure*

The cable as specified in the relevant specification shall be attached to the connector in accordance with the manufacturer's instructions. Unless otherwise specified the cable length shall be 100 mm to 150 mm.

The assembled connector shall be held or clamped in a horizontal position. A bending force shall then be applied to the cable by attaching to its free end a mass, sufficient to cause the cable to assume its minimum bend radius commencing at the point of cable entry into the connector.

The mass is then removed and the cable returned to its original straight position. These operations shall be regarded as one bending cycle.

The number of bending cycles shall be prescribed by the relevant specification.

9.3.9.2 *Requirements*

After the test, the cable shall still be firmly attached to the connector with no visible deterioration of the connector-to-cable junction.

9.3.9.3 *Information to be given in the relevant specification*

a) type of cable to be used;

b) minimum bending radius of the cable;

c) length of cable from cable outlet to point of attachment of the mass if other than 100 mm to 150 mm;

d) value of the mass necessary to produce the minimum bending radius;

e) number of bending cycles;

f) any deviation from the standard test method.

9.3.10 *Effectiveness of clamping device against cable torsion*

9.3.10.1 *Procedure*

The cable as specified in the relevant specification shall be attached in accordance with the manufacturer's instructions. Unless otherwise specified the length of the cable shall be 100 mm to 150 mm. The connector shall be suitably fixed.

An axial torque of specified magnitude shall be applied to the free end of the straight cable. Unless otherwise specified the torque shall be applied at a distance of at least 50 mm from the cable outlet and for a duration of 60 s minimum.

9.3.10.2 *Requirements*

The cable shall neither slip nor rotate in relation to the connector(s).

9.3.10.3 *Information to be given in the relevant specification*

a) the cable to be used and its length if not 100 mm to 150 mm;

b) value of the torque and method of its application;

c) duration of application of the torque if other than 60 s minimum;

d) any deviation from the standard test procedure.

9.3.11 *Strength of coupling mechanism*

9.3.11.1 *Object*

To determine the mechanical ability of the coupling mechanism to withstand an axial tensile force and, additional in the case of screw coupled connectors, a proof torque.

9.3.11.2 *Procedure*

An axial tensile force shall be applied smoothly to mated connector pairs the coupling of which, in the case of screw coupled connectors, has been tightened to the normal coupling torque.

In the case of screw coupled connectors, the coupling is then additionally tightened to the proof torque and loosened again three times.

Unless otherwise specified the applied force shall be maintained for a period of 60 s minimum.

9.3.11.3 *Requirements*

No damage shall occur and the coupling mechanism shall not fail.

If required by the relevant specification, the connector pairs shall then be subjected to the tests and measurements of 9.3.6 and shall meet the requirements specified by the relevant specification.

9.3.11.4 *Information to be given in the relevant specification*

a) value of the force and method of application;

b) duration of application of the force;

c) value of normal coupling torque;

d) value of proof torque;

e) number of connector pairs to be tested;

f) requirement whether or not the tests and measurements of 9.3.6 shall be applied;

g) any deviation from the standard test procedure.

9.3.12 *Bending moment (and shearing force)*

9.3.12.1 *Procedure*

Mated sets of connectors shall be subjected to a bending moment in such a way that the coupling mechanism is stressed.

One of the connectors shall be fixed either by the normal means of attachment (fixed connector), or by a suitably strong clamp (free connector). The bending moment shall be produced by a force perpendicular to the connector axis at a suitable distance from the reference plane. If appropriate a special mechanical test plug shall be used for this purpose. The force shall be applied smoothly.

NOTE – This method of producing the bending moment causes also a shearing force which may be kept small by using a long lever arm.

9.3.12.2 *Requirements*

No damage shall occur and the coupling mechanism shall not fail.

The connector pairs shall then be subjected to the tests and measurements of 9.3.6 and shall meet the requirements specified by the relevant specification.

9.3.12.3 *Information to be given in the relevant specification*

a) value of the force and the point of its application;

b) duration of application of the force;

c) any deviation from the standard test procedure.

9.3.13 *Bump*

9.3.13.1 *Procedure*

The bump test shall be carried out in accordance with IEC 68-2-29, on mated pairs of connectors.

The connectors shall be attached to a suitable length of appropriate cable and the mated pair of connectors mounted in one of the following ways as prescribed by the relevant specification:

a) clamping both the connectors and the cable;

b) clamping the cables only and thus leaving the connectors freely suspended;

c) if one of the connectors is a fixed style, this connector shall be mounted using the intended means;

With a) and c) the arrangements for mounting, and for clamping the cables shall be as in 9.1.1 unless otherwise specified.

Unless otherwise specified, the severities indicated in the relevant specification shall be chosen from the following preferred values:

Severity			
Peak acceleration		Duration	Number of bumps in each specified direction
g_n	(equivalent m/s²)	ms	
15	150	6	4 000 ± 10
40	400	6	1 000 ± 10
40	400	6	4 000 ± 10

The relevant specification shall state in which directions and senses the specified bumps shall be applied.

During the bumping the centre and outer contact continuity shall be monitored as specified in 9.2.4.

9.3.13.2 *Information to be given in the relevant specification*

a) appropriate cable to be used and its length;

b) details of mounting of connectors and cables;

c) severities;

d) directions and sense of conditioning;

e) performance requirements;

f) any deviation from the standard procedure.

9.3.14 *Shock*

9.3.14.1 *Procedure*

The shock test shall be carried out in accordance with IEC 68-2-27, on a mated pair of connectors.

The connectors shall be attached to a suitable length of appropriate cable and the mated pair of connectors mounted in one of the following ways as prescribed by the relevant specification:

a) clamping of both the connectors and the cable;

b) clamping the cables only and thus leaving the connectors freely suspended;

c) if one of the connectors is a fixed style this connector shall be mounted using the intended means;

With a) and c) the method of mounting and arrangements for clamping the cables shall be as in 9.1.1 unless otherwise specified.

The shock test severity to be prescribed by the relevant specification shall, preferably, be selected from amongst the following preferred values:

Severity			
Peak acceleration		Corresponding duration of nominal pulse	Pulse shape
g_n	(equivalent m/s²)	ms	
30	300	18	half-sine
50	500	11	half-sine
100	1 000	6	half-sine

The relevant specification shall state in which directions and senses the specified shocks shall be applied, and the number of shocks.

During each shock, the centre and outer contact continuity shall be monitored as specified in 9.2.4.

9.3.14.2 *Information to be given in the relevant specification*

a) appropriate cable to be used and its length;

b) details of mounting of connectors and clamping of cables if other than in 9.1.1;

c) severities;

d) directions and senses of shocks;

e) performance requirements;

f) any deviation from the standard procedure.

9.4 *Climatic conditionings and tests*

9.4.1 *Introduction*

9.4.1.1 *Survey of conditionings*

The climatic conditionings and tests comprise the following:

a) connectors of the climatic categories x/x/21 and x/x/56 shall be subjected to the climatic sequence based on the standard climatic sequence in clause 7 of IEC 68-1, consisting of the individual conditionings:

- dry heat; Test Ba, of IEC 68-2-2;
- damp heat, cyclic; first cycle of Test Db, of IEC 68-2-30;
- cold; Test Aa, of IEC 68-2-1;
- low air pressure; Test M, of IEC 68-2-13;
- damp heat, cyclic; remaining cycle(s) of Test Db;

b) test Ca; Damp heat, steady state, of IEC 68-2-3;

c) test Na; Change of temperature, of IEC 68-2-14, clause 1;

d) test Q; Sealing, of IEC 68-2-17;

e) test Ka; Salt mist, of IEC 68-2-11;

f) test Kc; Sulphur dioxide test for contacts and connections, of IEC 68-2-42;

g) test L; Dust and sand (under consideration).

9.4.1.2 *General procedure*

From a sub-sample of connectors subjected to the conditioning procedures and subsequent recovery period, half the numbers of specimens shall be mated and half the number shall stay unmated, unless otherwise specified.

An appropriate cable shall be attached to cable connectors and the free ends prepared in such a way that the inner and outer conductors can be electrically connected for measuring purposes. Where necessary the free ends shall be treated to prevent ingress of moisture. Fixed connectors shall be mounted in accordance with clause 9.1.1, and the back of panel portion shall, where appropriate, be protected against ingress of moisture.

NOTE - Special attention should be paid to connector specimens intended for the measurement of the reflection factor (see 9.2.1).

The climatic severities for the low and high temperatures, and the duration of the damp heat, steady state, exposure shall correspond to the climatic category of the connector, as prescribed in the relevant specification.

If applicable, the specimens shall be pre-conditioned and then visually examined and electrically and mechanically checked prior to subjecting them to the conditionings and tests, as prescribed in the relevant specification.

9.4.2 *Climatic sequence*

9.4.2.1 *Procedure*

The climatic sequence shall be carried out in accordance with Test Z/ABDM using the procedure and severities specified in the relevant specification. Unless otherwise prescribed Procedure 1 shall be used for qualification approval testing.

Unless otherwise prescribed in the relevant specification the low air pressure test (Test M) shall be carried out at a pressure of 4,4 kPa (44 mbar) for a duration of 1 h. During the last 5 min of the conditioning the low air pressure proof voltage prescribed in the relevant specification shall be applied. There shall be no breakdown or flash over.

NOTE - For test purposes 4,4 kPa (44 mbar) is considered to be the approximate equivalent air pressure at altitudes of 70 000 feet (approximately 20 km).

9.4.2.2 *Concluding tests*

The insulation resistance and voltage proof tests to be carried out within 15 min of removal from the chamber.

9.4.2.3 *Information to be given in the relevant specification*

a) climatic procedure if other than procedure 1;

b) pre-conditioning procedures, if any;

c) electrical and mechanical checks to be made before conditioning;

d) severity of each step of the applicable climatic procedure;

e) minimum value of insulation resistance at high temperature;

f) low air pressure proof test voltage(s);

g) requirements for the final measurements;

h) requirements for extended recover, if any;

i) any deviations from the standard test procedure.

9.4.3 *Damp heat, steady state*

9.4.3.1 *Procedure*

This test shall be carried out in accordance with Test Ca of IEC 68-2-3, using the appropriate degree of severity.

Immediately after removal of the specimens from the chamber they shall be shaken to remove surface moisture and within 15 min the sea-level environmental test voltage as specified in the relevant specification shall be applied between the centre and outer conductor(s) of the connectors for 5 min. In the case of tri-axial connectors, an appropriate test voltage as specified in the relevant specification shall be applied between the outer conductor and screen. There shall be no breakdown or flashover.

The specimens shall then be exposed to the standard atmospheric recovery conditions for 1 h 30 to 2 h.

9.4.3.2 *Final tests and measurements*

At the conclusion of the recovery period the connectors shall meet the requirements of the relevant specification for the following properties, unless otherwise specified:

Mated connectors

a) Contact resistance
b) Voltage proof
c) Visual inspection

Unmated connectors

a) Insulation resistance
b) Voltage proof
c) Contact resistance on resilient contacts individually
d) Visual inspection

NOTES

1 The insulation resistance measurement and the voltage proof test should be carried out within 30 min of the recovery period.

2 The mated connectors should not be disturbed prior to the contact resistance measurement.

9.4.3.3 *Information to be given in the relevant specification*

a) voltage for the test immediately after conditioning;
b) requirements for the final measurements;
c) any deviation from the standard procedure.

9.4.4 *Rapid change of temperature*

9.4.4.1 *Procedure*

This test shall be carried out in accordance with Test Na of IEC 68-2-14.

The low conditioning temperature shall be the low category temperature, and the high temperature the high category temperature of the specimens.

Unless otherwise prescribed in the relevant specification the number of cycles shall be five, the transition time 2 min to 3 min and the duration of exposure at each of the two temperatures 30 min. A longer period of exposure may be prescribed by the relevant specification if required to ensure thermal equilibrium is achieved.

At the end of the last cycle, the specimens shall be subjected to standard atmospheric conditions for recovery for 1 h 30 to 2 h.

9.4.4.2 *Final tests and measurements*

At the conclusion of the recovery period, the connectors shall meet the requirements of the relevant specification for the following properties, unless otherwise specified:

Mated connectors

a) Contact resistance
b) Voltage proof
c) Visual inspection

Unmated connectors

a Insulation resistance
b) Voltage proof
c) Contact resistance on resilient contacts individually
d) Sealing
e) Visual inspection

NOTES

1 The insulation resistance measurement and the voltage proof test should be carried out within 30 min of the recovery period.

2 The mated connectors should not be disturbed prior to the contact resistance measurement.

9.4.4.3 *Information to be given in the relevant specification*

a) requirements for the final tests and measurements;

b) any deviation form the standard test procedure.

9.4.5 *Sealing*

9.4.5.1 *Non-hermetic sealed connectors*

9.4.5.1.1 *General*

Non-hermetic sealed connectors are connectors with seals of any kind whose leakage may have a magnitude detectable by one of the test methods Qa or Qc of IEC 68-2-17.

The connectors are regarded as having type B seals (seals working in both directions), but a test in one direction only, as for type A seals, is considered satisfactory.

9.4.5.1.2 *Procedure*

The test shall be carried out in accordance with Test Qa of IEC 68-2-17.

Panel sealed, as well as panel and barrier sealed connectors (thus fixed connectors) shall be mounted on a rigid plate forming part of a test jig (a closed box) permitting the application of the required air pressure.

Free connectors fitted both with barrier and mating face seals shall be tested by mating them with an appropriate complementary fixed connector permanently mounted with a panel seal to the test jig but allowing the passage of air to the free space inside the mated connectors.

Free connectors fitted only with barrier seal, but no mating face seal, shall be appropriately sealed to the test jig. This may be achieved by means of a constricting compression gland of a suitable size to grip the body shell.

9.4.5.1.3 *Requirements*

At the standard pressure difference of 100 kPa to 110 kPa (1 bar to 1,1 bar), the leakage rate shall not exceed the limit given by the relevant specification; in no case, however, shall it exceed 1 bar cm^3/h.

9.4.5.1.4 *Information to be given in the relevant specification*

a) requirements for pressure;

b) requirements for leakage rates;

c) any deviation from the standard test procedure.

9.4.5.2 *Hermetically sealed connectors*

9.4.5.2.1 *Procedure*

The test shall be carried out in accordance with Test Qk of IEC 68-2-17, using the tracer gas procedure covered by amendment 3.

The last sentence of note 2 in 6.2 of amendment 3 shall be disregarded. However, to ensure that an undetected shift in the sensitivity of the set-up has not occurred during the test period, the calibration of the system shall be re-checked using the reference leak at the conclusion of testing.

In the event of a significant change occurring in the calibration during a test period, it will be necessary to retest the connector(s) involved once the stability of calibration has been re-established.

For quantitative measurements, the test set-up shall be calibrated, using a calibrated leak in place of the connector to be tested.

Leaks at the test specimen may be localized by sweeping it with a fine jet of helium at low pressure, the flexible pocket or the cap, of course, being omitted.

9.4.5.2.2 *Requirements*

The leakage rate under standard conditions as mentioned above shall not exceed 10^{-3} Pa cm³/s (10^{-8} bar cm³/s), unless otherwise prescribed by the relevant specification.

9.4.5.2.3 *Information to be given in the relevant specification*

a) test parameter, if different from the standard value(s);

b) limit of leakage rate, if different from the value mentioned above;

c) any deviation from the standard procedure.

9.4.6 *Salt mist*

For either of the salt mist tests, the cable connectors shall have the appropriate cable attached, with the free ends treated to prevent ingress of moisture. Unless otherwise prescribed by the relevant specification, half of the specimens shall be mated and half un-mated.

9.4.6.1 *Salt mist (corrosion)*

This test shall be carried out in accordance with Test Ka of IEC 68-2-11. Unless otherwise prescribed, the duration of spraying shall be 48 h.

At the conclusion of the recovery procedure and period, the connectors shall meet the requirements as follows, unless otherwise prescribed by the relevant specification:

a) visual inspection;

b) engagement and separation shall be achievable by hand, or in the normal manner.

9.4.6.2 *Salt mist, cyclic (marine environment)*

This test shall be carried out in accordance with Test Kb of IEC 68-2-52, at the severity prescribed by the relevant specification which may also prescribe the use of the simulated sea-water solution given in annex A of this specification. The unmated connectors shall be fitted with protective covers.

Within 15 min. after removal from the chamber at the conclusion of the conditioning, the relevant environmental test voltage shall be applied to the connectors between the centre and outer conductors for 5 min. There shall be no breakdown or flashover. The connectors shall then be washed as indicated in the specification. At the conclusion of the recovery period, measurements shall be made on the mated sets of connectors as below:

Mated connectors

a) inner and outer conductor continuity
b) insulation resistance
c) voltage proof
d) visual inspection
e) separation and engagement achievable in the normal manner

Connectors with protective caps

a) insulation resistance
b) voltage proof
c) visual inspection
d) separation and engagement achievable in the normal manner

9.4.7 *Dust*

Under consideration

9.4.8 *Sulphur dioxide test*

9.4.8.1 *Procedure*

This test shall be carried out in accordance with Test Kc of IEC 68-2-42. Unless otherwise specified, the direct injection method of generating the conditioning atmosphere as given in annex A of the publication shall be used.

NOTE - This test may be preceded by the mechanical endurance test.

The duration of exposure to be prescribed by the relevant specification shall, preferably, be selected from amongst the following preferred values: 4, 10 or 21 days.

The specimens shall then be removed from the chamber and stored under standard atmospheric recovery conditions for 1 h 30 to 2 h.

9.4.8.2 *Final tests and measurements*

At the conclusion of the recovery period, the connectors shall meet the requirements of the relevant specification for the following properties, unless otherwise specified:

Mated connectors

a) Contact resistance
b) Visual inspection

Unmated connectors

a) Contact resistance, immediately after first engagement of pairs
b) Visual inspection

NOTE - The mated connectors should not be disturbed prior to contact resistance measurement.