IEC TS 61169-1-51

Edition 1.0 2020-10

TECHNICAL SPECIFICATION

colour inside

Radio frequency connectors –
Part 1-51: Technical specification of electrical tests – Uncertainty specification of frequency domain test for return loss

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FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61169-1-51, which is a Technical Specification, has been prepared by subcommittee 46F: RF and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
46F/488/DTS	46F/495/RVDTS

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

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

A list of all parts in the IEC 61169 series, published under the general title *Radio frequency connectors*, can be found on the IEC website.

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

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- withdrawn,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

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

INTRODUCTION

This document relates to technical requirements for electrical tests for radio frequency connectors. In IEC 61169-1:2013, a frequency domain test method has been described. However, the document does not contain the quantitative uncertainty specification for measurement instruments, i.e. vector network analysers and terminations, for return loss. This document shows quantitative uncertainty specifications of electrical tests for return loss of radio frequency connectors. In addition, the document includes a brief analysis of vector network analyser measurement uncertainty for return loss measurements of radio frequency connectors.

RADIO FREQUENCY CONNECTORS –

Part 1-51: Technical specification of electrical tests – Uncertainty specification of frequency domain test for return loss

1 Scope

This part of IEC 61169, which is a Technical Specification, relates to radio frequency connectors for RF transmission lines for use in telecommunications, electronics and similar equipment.

It provides the technical report for the uncertainty specifications for return loss measurements, which apply to individual connector types, by vector network analysers (VNAs). It is intended to establish concepts and procedures considering:

– testing and measuring procedures concerning frequency domain electrical properties;
– uncertainty specifications of VNAs measurements for return loss of RF connectors.

The test methods and procedures of this document are intended for acceptance and type approval testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027, *Letter symbols to be used in electrical technology*

IEC 60050, *International Electrotechnical Vocabulary*
(available from: http://www.electropedia.org)

IEC 60617, *Graphical symbols for diagrams*

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

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC Guide 98-1, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

ISO 1000:1992[1], *SI units and recommendations for the use of their multiples and of certain other units*

1 Withdrawn in 2009, revised by ISO 80000-1:2009.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61169-1 apply.

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

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

4 Units, symbols and dimensions

4.1 Units and symbols

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

a) IEC 60027: Letter symbols to be used in electrical technology,

b) IEC 60050: International Electrotechnical Vocabulary (IEV),

c) IEC 60617: Graphical symbols for diagrams.

Other publication:

ISO 1000:1992[2]: SI units and recommendations for the use of their multiples and of certain other units.

5 Report characteristics

The report characteristics applicable to each connector type and style are recommended to the relevant specifications of return loss measurements. They normally cover the return loss as a function of operation frequency for the different grades (if applicable) together with the conditions for which it is valid.

6 Return loss in frequency domain tests

6.1 Parameters

Return loss is a useful parameter for specifying the characteristics of RF connectors. However, the following three representations are also widely used:

1) reflection coefficient: $\Gamma = a + jb$

   where a is real part, b is imaginary part),

2) return loss: Return loss = –20 log(|Γ|) (dB),

3) voltage standing wave ratio ($VSWR$): $VSWR = (1+|\Gamma|)/(1-|\Gamma|)$.

6.2 General considerations

Measurement/testing results, or specification, of return loss should not only include exact measurement values but also error/uncertainty in VNA measurement (Figure 1 and Figure 2). Classification of return loss of connector(s) is decided from the combination of the exact measurement value and its uncertainty for test specimen.

2 Withdrawn in 2009, revised by ISO 80000-1:2009.

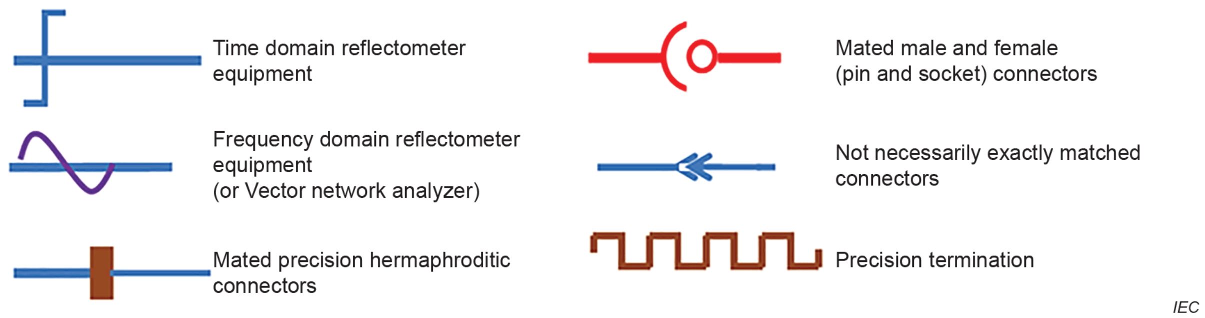

Figure 1 – Graphical symbols

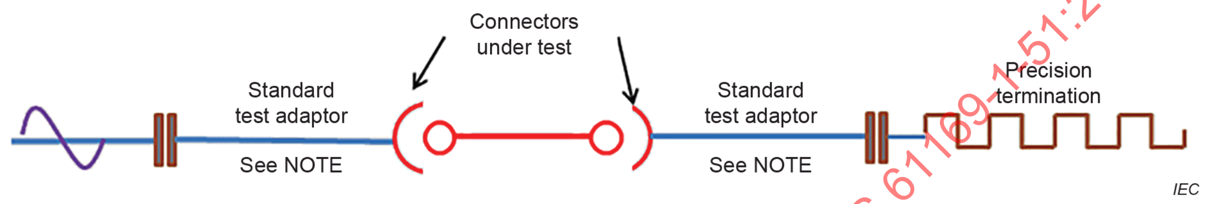

Figure 2 – Graphical principle

NOTE Standard tests connectors are either directly used on the analyser port, analyser test leads and/or the precision termination or are connected through standard test adaptors.

6.3 Test equipment

6.3.1 General requirement

Total value of accuracy, i.e. error/uncertainty, of VNA for return loss testing for connector(s) should be smaller than measurement values or design values of connector(s).

6.3.2 VNA calibration uncertainty

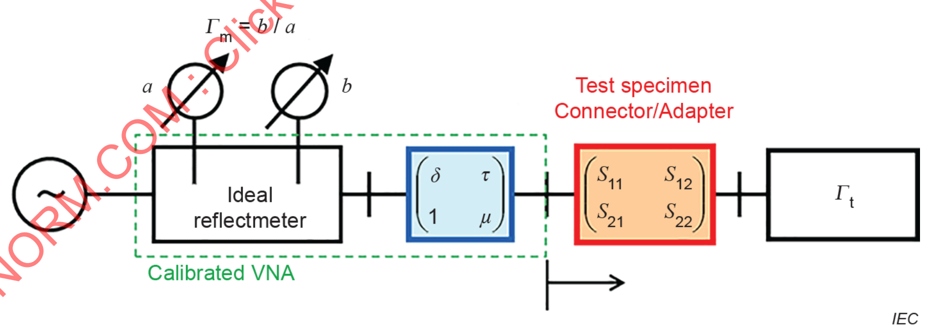

Figure 3 – VNA measurement model

The so-called error terms of a VNA (Figure 3) can be calculated by connecting several calibration standards and applying a suitable calibration method. However, the VNA measurement uncertainty depends on the calibration standards and method. In one port VNA measurement (return loss measurement), the uncertainty can be described by the three so-called residual error terms delta, tau and mu.

The VNA measurement model is shown in Figure 1. The characteristics of the test specimen, Γ, are represented by the following equations for the linear reflection coefficient (complex, no units).

$$\Gamma_m = \delta + \tau\Gamma \,/\, (1-\mu\Gamma) \tag{1}$$

where Γ_m is the measurement value obtained by the VNA, and δ, μ, and τ indicate the residual error terms: directivity error, source match error, and reflection tracking error.

If the reflection coefficient of the test specimen is small, i.e. $|\Gamma| < 0{,}1$ (VSWR < 1,2), the dominant error term is δ, and equation (1) can be rewritten:

$$\Gamma_m \approx \delta + \Gamma \tag{2}$$

According to equation (2), the directivity error shall be known for return loss measurement of connectors.

The worst case of measurement value is

$$|\Gamma_m| \approx |\delta| + |\Gamma| \tag{3}$$

The directivity error magnitude $|\delta|$ and its uncertainty $\mu(|\delta|)$ can be estimated by following two ways.

– Referring to the data sheet provided from the instrumentation manufacture. This might provide a somewhat overestimated value.
– Comparing between measurement values and reference values of matched load termination(s) calibrated by the upper level calibration laboratory, i.e. the ISO/IEC 17025 accredited calibration laboratories, or national measurement laboratories, etc. This provides exact value, δ, of directivity and its uncertainty, $\mu(\delta)$. Examples of uncertainty analysis are explained in Annex A.

6.3.3 Terminating load specification

For the return loss testing, the test specimen, connector, is terminated by a matched load. According to the model in Figure 3, the reflection coefficient of the test specimen, S_{11}, is represented by the following equations.

$$\Gamma_m = S_{11} + S_{21}S_{12}\tau\Gamma_t \,/\, (1-S_{22}\Gamma_t) \tag{4}$$

where Γ_m is the measurement value of the reflection coefficient of test specimen and S_{11}, S_{21}, S_{12} and S_{22} are the scattering parameters.

If the reflection coefficient is small, i.e. $|S_{11}|$ and $|S_{22}| < 0{,}1$ ($VSWR < 1{,}2$), and S_{21} and S_{12} are approximately 1,0 (0 dB), then equation (4) can be rewritten as follows:

$$\Gamma_m \approx S_{11} + \Gamma_t \; \Gamma_m \approx \delta + \Gamma \tag{5}$$

According to equation (5), the termination shall be known for return loss measurement of connectors.

The worst case of measurement value is

$$\Gamma_m \leq |S_{11}| + |\Gamma_t| \tag{6}$$

Characteristics of termination(s) and its uncertainty can be obtained by the upper level calibration laboratory, i.e. the ISO/IEC 17025 accredited calibration laboratories, or National measurement laboratories, etc.

6.3.4 Other test conditions

The measurement uncertainty depends on the measurement conditions and the setup of the VNA. Major contributions to the measurement uncertainty for return loss measurements of connectors (excluding calibration described in 6.3.2) are:

a) noise floor/trace noise,

b) connector mated interface, e.g. connector pin recession and/or scratch, etc.

The error source of setting conditions/parameters shall be minimized on your own testing system including VNA.

6.3.5 Total test uncertainty

The total test uncertainty for return loss measurements on connector(s) results from 6.3.2. The expanded uncertainty (equal and greater than 95 %), described by the ISO/IEC Guide 98-1, is:

$$U(|\Gamma_{\mathrm{m}}|) = 2 \times \sqrt{\{|\delta|/\sqrt{2} + \mu\,(|\delta|)\}^2 + \{|\Gamma_{\mathrm{t}}|/\sqrt{2} + \mu\,(|\Gamma_{\mathrm{t}}|)\}^2 + x^2} \quad (7)$$

The x stands for additional uncertainty sources that depend on the individual VNA system and shall be taken into account by the user.

Annex A
(informative)

Estimation of VNA uncertainty specifications from commercial standard devices

A.1 Estimation from calibration certificate

Calibration certificates can be derived from the National Metrology Institute, the ISO/IEC 17025 accredited calibration laboratories or similar laboratories. Calibration certificates provides calibration data and their uncertainties of the calibrated standard devices. Uncertainty specification of return loss measurements can be estimated by using their uncertainties listed in the certificate. Estimation can be derived by following instructions.

If the following calibration results of load device are provided from the calibration laboratory;

Calibration data, $|\Gamma|$ = 0,010 and expanded uncertainty (k=2) of $U(|\Gamma|)$ = 0,002.

When the load device is used as VNA calibration standard, according equation (3), $|\delta|$ = 0,010 and $U(|\delta|)$ = 0,002, ($\mu(|\delta|)$ = 0,001).

In addition, when the load device is used as termination of the test specimen, according equation (3), $|\Gamma_t|$ = 0,010 and $U(|\Gamma_t|)$ = 0,002, ($\mu(|\delta|)$ = 0,001).

Finally, according to equation (7), the total uncertainty of return loss measurement from the load device is

$$
\begin{aligned}
U(|\Gamma_m|) &= 2 \times \sqrt{\{|\delta|/\sqrt{2} + \mu(|\delta|)\}^2 + \{|\Gamma_t|/\sqrt{2} + \mu(|\Gamma_t|)\}^2} \\
&= 2 \times \sqrt{\{0{,}010/\sqrt{2} + 0{,}001\}^2 + \{0{,}010/\sqrt{2} + 0{,}001\}^2} \\
&= 2 \times 0{,}011414 \\
&= 0{,}023
\end{aligned}
\qquad (A.1)
$$

A.2 Estimation from data/specification sheet

Data/specification sheet of calibration kit or precision terminations is usually provided from the instrumentation manufacturer. Data/specification sheet gives specification of return loss measurements for the standard devices. Uncertainty specification of return loss measurement can be estimated by using their data/specification given by the sheet. Estimation can be derived by following instructions.

If following data/specification of load device can be used;

Data/specification: $|\Gamma| + \mu(|\Gamma|)$ = 0,020.

Usually, Data/specification, $|\Gamma| + \mu(|\Gamma|)$, of the commercial devices is decided from calibration/test results including many types of uncertainty factors, i.e. temperature drift and long term stability of return loss measurement, etc..

When the load device is used as VNA calibration standard, according equation (3), $|\delta| + \mu\,(|\delta|) = 0{,}020$.

In addition, when the load device is used as termination of the test specimen, according equation (3), $|\Gamma_t| + \mu\,(|\Gamma_t|) = 0{,}020$.

Finally, according to equation (7), the total uncertainty of return loss measurement from the load device is

$$\begin{aligned} U(|\Gamma_m|) &= 2 \times \sqrt{\{|\delta|/\sqrt{2} + \mu\,(|\delta|)\}^2 + \{|\Gamma_t|/\sqrt{2} + \mu\,(|\Gamma_t|)\}^2} \\ &= 2 \times \sqrt{\{0{,}020/\sqrt{2}\}^2 + \{0{,}020/\sqrt{2}\}^2} \\ &= 2 \times 0{,}020 \\ &= 0{,}040 \end{aligned} \qquad \text{(A.2)}$$