IEC 61196-1-125

Edition 1.0 2022-09

INTERNATIONAL STANDARD

Coaxial communication cables – Part 1-125: Electrical test methods – Test for equivalent relative permittivity and equivalent dissipation factor of dielectric

IEC 61196-1-125:2022-09(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

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

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

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

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 It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

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

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 61196-1-125

Edition 1.0 2022-09

INTERNATIONAL STANDARD

Coaxial communication cables – Part 1-125: Electrical test methods – Test for equivalent relative permittivity and equivalent dissipation factor of dielectric

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.120.10

ISBN 978-2-8322-5606-0

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

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

COAXIAL COMMUNICATION CABLES –

Part 1-125: Electrical test methods – Test for equivalent relative permittivity and equivalent dissipation factor of dielectric

FOREWORD

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

IEC 61196-1-125 has been prepared by subcommittee 46A: Coaxial cables, of IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories. It is an International Standard.

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

Draft	Report on voting
46A/1581/FDIS	46A/1596/RVD

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

The language used for the development of this International Standard is English.

A list of all parts in the IEC 61196 series, published under the general title *Coaxial communication cables*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

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

COAXIAL COMMUNICATION CABLES –

Part 1-125: Electrical test methods – Test for equivalent relative permittivity and equivalent dissipation factor of dielectric

1 Scope

This part of IEC 61196 specifies the test method to determine the equivalent relative permittivity and dissipation factor of dielectric for coaxial cables. It is intended to provide the dielectric properties of finished cables.

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

IEC 61169-1-2:2019, *Radio-frequency connectors – Part 1-2: Electrical test methods – Insertion loss*

IEC 61196-1, *Coaxial communication cables – Part 1: Generic specification – General, definitions and requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61196-1 and IEC 61169-1 apply.

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

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

3.1
relative permittivity
ε_r
ratio of the capacitance of a capacitor using that material as a dielectric, compared to a similar capacitor that has vacuum as its dielectric

3.2
equivalent relative permittivity
ε_e
relative permittivity for a complex medium

3.3
dissipation factor
tanδ
absolute value of the ratio of the imaginary to the real part of the complex relative permittivity

3.4
equivalent dissipation factor
tanδ_e
dissipation factor for a complex medium

4 Principal

The sinusoidal electromagnetic fields can be expressed as a Maxwell Equation as the following:

$$\begin{cases} \mathrm{rot}\dot{H} = g\dot{E} + j\omega\varepsilon\dot{E} = j\omega\dot{\varepsilon}\dot{E} \\ \mathrm{rot}\dot{E} = -j\omega\mu\dot{H} \end{cases}$$

where

$\dot{H}$ is the magnetic field intensity, expressed in A/m;

$\dot{E}$ is the electric field intensity, expressed in V/m;

g is the conductivity, expressed in S/m;

ω is the angular frequency, expressed in rad/s;

ε is the absolute permittivity, expressed in F/m;

μ is the absolute permeability, expressed in H/m;

$\dot{\varepsilon}$ is a complex form of medium absolute permittivity.

$\dot{\varepsilon}$ can be derived as:

$$\dot{\varepsilon} = \frac{g + j\omega\varepsilon}{j\omega} = \varepsilon\left(1 + \frac{g}{j\omega\varepsilon}\right) = \varepsilon\left(1 - j\frac{g}{\omega\varepsilon}\right) = \varepsilon(1 - j\tan\delta)$$

where

$\tan\delta$ is the dissipation factor, no unit.

ε, $\tan\delta$, g and μ are the most important parameters for the insulation characteristics. And they can also be derived as:

$$\begin{cases} \varepsilon = \varepsilon_0 \cdot \varepsilon_r \\ \mu = \mu_0 \cdot \mu_r \end{cases}$$

where

ε_0 is the absolute permittivity of vacuum, expressed in F/m;

μ_0 is the absolute permeability of vacuum, expressed in H/m;

ε_r is the relative permittivity, no unit;

μ_r is the relative permeability, no unit.

In SI units:

$$\varepsilon_0 \approx \frac{1}{36\pi}\cdot 10^{-9} \text{ F/m or } \varepsilon_0 = \frac{1}{\mu_0 \cdot c_0^2} \text{ F/m}$$

$$\mu_0 \approx 4\pi\cdot 10^{-7} \text{ H/m},$$

c_0 is the speed of light in vacuum, c_0 = 299 792 458 m/s

For cable design, ε_0 and μ_0 are the constant values. Besides, μ_r is also a constant value if the conductor is a non-magnetic material and it equals 1. So, ε_r is the only parameter that needs to be computed.

However, the insulation structure in the coaxial cable is not a homogeneous one. Conversely, a combination of material and air with complicated complexes constitute various coaxial cables.

Therefore, the equivalent relative permittivity ε_e and equivalent dissipation factor $\tan\delta_e$ are needed and they represent the ε_r and $\tan\delta_r$ of the complex medium in the finished coaxial cable, respectively.

5 Test procedures

5.1 Preparation of specimen

The specimen needs to be well prepared by making a cable assembly with uniform characteristic impedance of the connectors at both ends. For the ultra-low loss cable, the connectors at both ends have an obvious contribution to the total loss. For the purpose of this recommendation, the round-trip loss of the specimen should be greater than 40 dB.

If the cable has a very short reach application, the round-trip loss may be less than 40dB. In this case, the connectors' insertion loss shall be taken into account in accordance with IEC 61169-1-2:2019, 4.1.1, method 1.

5.2 Equipment

The following equipment may be used:

– A vector network analyser (VNA) capable of performing S_{21} measurements.

– A set of mechanical or electronic calibration standard kits. Their frequency range should cover the entire test frequency range.

5.3 Calibration

The attenuation of the test setup (including the test leads and connectors) should be calibrated by performing S_{21} measurements over the whole specified frequency range. As the phase delay is used for calculating the equivalent relative permittivity, the minimum number of measurement points should be determined using the following formula:

$$N \geq \left[(f_2 - f_1)/40\right]\cdot L$$

where

f is the frequency, expressed in MHz;

L is the length, expressed in m.

5.4 Measurement

5.4.1 Equivalent relative permittivity

Connect the specimen to the test ports of calibrated VNA. The phase constant should be measured over the whole specified frequency range. According to IEC 61196-1-108:2011, the phase delay τ_p can be computed by the following formula:

$$\tau_p(f) = \frac{\beta(f)}{2\pi \cdot f}$$

where

$\beta(f)$ is the phase constant at frequency f, expressed in radians/m;

$2\pi \cdot f$ is the angular frequency f, expressed in radians/s;

$\tau_p(f)$ is the phase delay at frequency f, expressed in s/m.

The phase delay τ_p can be used for calculating the equivalent relative permittivity in accordance with 6.1.

5.4.2 Equivalent dissipation factor

Connecting the specimen to the test ports of calibrated VNA. The attenuation constant should be measured over the whole specified frequency range.

If the round-trip loss is less than 40 dB, the real attenuation of the cable should be calculated by subtracting the loss of the connectors in accordance with IEC 61169-1-2:2019, 5.3.1, method 1.

The attenuation constant can be used for calculating the equivalent dissipation factor angle δ in accordance with 6.2.

6 Expression of test results

6.1 Expression of equivalent relative permittivity

The equivalent relative permittivity ε_e can be computed by a simultaneous equation:

$$\begin{cases} v(f) = \dfrac{1}{\sqrt{\varepsilon \cdot \mu}} = \dfrac{1}{\sqrt{\varepsilon_0 \cdot \varepsilon_e \cdot \mu_0 \cdot \mu_e}} = \dfrac{1}{\sqrt{\dfrac{1}{36\pi} \times 10^{-9} \times \varepsilon_e \times 4\pi \times 10^{-7} \times 1}} \approx \dfrac{3 \times 10^8}{\sqrt{\varepsilon_e}} \\ \tau_p = \dfrac{1}{v(f)} \end{cases}$$

where

$v(f)$ is the propagation velocity at frequency f, expressed in m/s;

ε_e is the equivalent relative permittivity, no unit;

μ_e is the equivalent permeability, no unit.

NOTE μ_e is a constant value if the conductor is a non-magnetic material and it equals 1.

6.2 Expression of equivalent dissipation factor

The equivalent dissipation factor angle δ can be computed by the following steps:

a) In accordance with IEC 61196-1-113:2018, the attenuation constant of a cable as a function of frequency can be expressed as shown in the following equation:

$$\alpha_{\text{fit}}(f) = A\sqrt{f} + Bf + C + \frac{D}{\sqrt{f}}$$

where

α_{fit} is the fitted attenuation of the attenuation constant, in dB/100 m;

f is the frequency, in MHz;

A is the coefficient for the losses in the inner and outer conductors owing to the skin effect;

B is the coefficient for dielectric loss;

C is the constant component;

D is the optional coefficient for the losses in copper-clad conductors.

By using the form fitting, the coefficient A, B, C, D can be calculated in the following matrix:

$$\begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{N} f_i & \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{1/2} & N \\ \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{2} & \sum_{i=1}^{N} f_i & \sum_{i=1}^{N} f_i^{1/2} \\ \sum_{i=1}^{N} f_i^{1/2} & \sum_{i=1}^{N} f_i & N & \sum_{i=1}^{N} f_i^{-1/2} \\ N & \sum_{i=1}^{N} f_i^{1/2} & \sum_{i=1}^{N} f_i^{-1/2} & \sum_{i=1}^{N} f_i^{-1} \end{bmatrix}^{-1} \begin{bmatrix} \sum_{i=1}^{N} \alpha(f_i) \cdot f_i^{1/2} \\ \sum_{i=1}^{N} \alpha(f_i) \cdot f_i \\ \sum_{i=1}^{N} \alpha(f_i) \\ \sum_{i=1}^{N} \alpha(f_i) \cdot f_i^{-1/2} \end{bmatrix}$$

NOTE Sometimes, the form fitting has an over-smooth effect for the measured values and the coefficient C turns out to be a negative value. In this case, the coefficient C shall revert to zero.

b) With the determined coefficient B and the known parameter ε_e from 6.1, the equivalent dissipation factor angle δ can be calculated with by using the following formula:

$$\tan\delta_e = \frac{B}{9{,}1\sqrt{\varepsilon_e}}$$

where

$\tan\delta_e$ is the equivalent dissipation factor angle δ, no unit.

7 Test report

Test report shall give the following information:

– test sample length;

– test temperature;

– test parameter.

8 Requirements

The characteristic values of equivalent relative permittivity and equivalent dissipation factor should not exceed the range of design values specified in the detail specification.