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INTERNATIONAL STANDARD

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

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FOREWORD

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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- withdrawn,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:

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

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:

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

where

tanδ is the dissipation factor, no unit.

ε, tanδ, 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 tanδ_e are needed and they represent the ε_r and tanδ_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:

$$\tau_\text{p}(f) = \frac{\beta(f)}{2\pi \cdot f}$$

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;

$\tau_\text{p}(f)$ 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:

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

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.