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INTERNATIONAL STANDARD

Coaxial communication cables –
Part 1-113: Electrical test methods – Test for attenuation constant

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FOREWORD

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IEC 61196-1-113 has been prepared by subcommittee 46A: Coaxial cables, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This third edition cancels and replaces the second edition published in 2018. This edition constitutes a technical revision.

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

a) add Clause 3 "Terms and definitions";
b) add Clause 4 "Test environment";
c) add Clause 5 "Preconditioning";
d) add Subclause 7.1 "General";

e) add detail test methods including 7.2 "long cable methods" and 7.3 "double-cable method";
f) add "Annex A Stability of attenuation constant at different temperatures";
g) add "Annex B Test examples of stability of attenuation constants at different temperature".

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

Draft	Report on voting
46A/1688/FDIS	46A/1693/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.

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.

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.

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- withdrawn, or
- revised.

COAXIAL COMMUNICATION CABLES –

Part 1-113: Electrical test methods – Test for attenuation constant

1 Scope

This part of IEC 61196 applies to coaxial communications cables. It specifies a test method for determining the attenuation constant of coaxial cables for use in communications systems. The test is applicable preferably at frequencies ≥5 MHz but also for lower frequencies if the magnitude of the complex characteristic impedance is approximately equal to the nominal characteristic impedance of the test sample (TS) or if a form fitting function is applied.

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 61196-1, *Coaxial communication cables – Part 1: General 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 the following apply.

ISO and IEC maintain terminology 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
attenuation constant
real part of the propagation coefficient, defined as

$$\alpha = 10 \cdot \log_{10}\left(\frac{P_1}{P_2}\right) \cdot \frac{100}{l} \tag{1}$$

where

α is the attenuation constant of the cable, dB/100 m;

P_1 is the output power of a source where the load impedance and the source impedance are equal and of the same value as the nominal value of the test sample (TS), W;

P_2 is the output power measured when the test sample (TS) is inserted into the test system, where the load impedance and the source impedance are equal and of the same value as the nominal value of the test sample (TS), W;

l is the physical length of the test sample (TS), m.

4 Test environment

The test should be carried out at normal temperature, and the change range of ambient temperature should be kept within ±2 °C.

5 Preconditioning

The test samples (TS) should be stable at the ambient temperature for at least 4 h while recording the ambient temperature.

6 Equipment

The following equipment can be used:

a) a vector network analyser (VNA);

b) length measuring instruments with accuracy not exceeding one thousandth of the length of the test sample (TS);

c) the connectors adapted to the TS should preferably match and connect with VNA test ports;

d) if impedance matching adapters are needed, they shall be provided to match the impedance of the VNA and that of the test sample (TS). In that case, the impedance of the impedance matching adapters shall meet Formula (2).

$$\left|\frac{Z_{\text{TS}} - Z_{\text{adapter}}}{Z_{\text{TS}} + Z_{\text{adapter}}}\right| \le 0{,}05 \quad (2)$$

where

Z_{TS} is the nominal characteristic impedance of the test sample (TS);

Z_{adapter} is the nominal impedance of the matching adapter at the secondary side.

In the above case, the reflection loss errors due to the mismatch can be neglected (≤ 0,02 dB).

7 Test method

7.1 General

The following three test methods can be used to test the attenuation constant of a cable.

a) Method 1: long cable method, that is, a cable with sufficient length is connected to a pair of connectors to form a cable assembly as a test sample (TS), and the insertion losses of the pair of connectors is negligible. The measured insertion loss of assembly can be used to calculate the attenuation constant of the cable directly. This method is suitable for measuring the cable attenuation constant only when the insertion loss of the pair of connectors can be ignored comparing that of the cable.

b) Method 2: double-cable method, that is, two pieces of cables with different lengths are cut from a cable under test and connected respectively to a pair of connectors with same type and specification and quality, to form two cable assemblies as test samples (TS). The measured insertion loss of two cable assemblies can be used to calculate the attenuation constant. The method is suitable for measuring the cable attenuation constant only when the difference between insertion losses of two pair of connectors can be ignored.

c) Method 3: when needed, the stability of attenuation constant of coaxial cable can be tested by testing the changing ratio of its attenuation constants at different temperatures relative to its attenuation constant at 20 °C.

The test method of stability of attenuation constant that shall be used is specified in Annex A. The example of stability of attenuation constant at different temperature is shown in Annex B.

7.2 Method 1 – Long cable method

7.2.1 Preparation of test sample (TS)

The TS shall be terminated with a pair of connectors which shall be well matched to the cable and can be connected to VNA directly. The cable shall be long enough so that the insertion loss of the connector pair can be negligible compared with that of the cable.

To improve test accuracy, it is recommended that the connectors at both ends of the TS are threaded RF coaxial connectors pair which can connect VNA directly.

If, at low frequencies, the deviation between the size of the complex characteristics of the sample impedance and the nominal characteristic impedance cannot be ignored, the sample length l should be such that the attenuation of the sample at the minimum frequency to be measured is greater than 20 dB, which will avoid the influence of multiple reflections at both ends of the sample. Alternatively, the fit function can be applied.

7.2.2 Test procedure

The test procedure shall be as follows.

a) After VNA is fully preheated, set the measurement frequency range and the test mode to S12 or S21. According to user needs, choose linear scanning or logarithmic scanning as the scanning mode. The number of scanning points shall be set according to Formula (3) and should not be less than 801 points. When the value calculated according to Formula (3) exceeds the maximum number of points of the device, the highest number of points that VNA can reach should be taken.

$$n \geq \frac{3(f_2 - f_1)l}{120} \tag{3}$$

where

n is the number of scanning points of measurement;

f_1 is the lowest point of the frequency range in MHz;

f_2 is the highest point of the frequency range in MHz;

l is the physical length of the TS in metres (m).

b) System calibration: full two port calibration shall be performed at the ends of the test cables.

c) Connect TS to VNA and measure the insertion loss $IL(f)$ of the TS.

d) Calculate the attenuation constant according to Formula (4):

$$\alpha(f) = \mathrm{IL}(f) \cdot \frac{100}{l} \tag{4}$$

where

$\alpha(f)$ is the attenuation constant of the cable, dB/100 m;

$\mathrm{IL}(f)$ is the measured insertion loss, dB;

l is the physical length of the TS, m.

7.3 Method 2 – Double cable method

7.3.1 Preparation of test sample (TS)

Cut two pieces of cables with different lengths from a cable under test; each piece of cable shall be connected to a pair of connectors to form a cable assembly as test sample (TS). The two pairs of connectors shall be the same type, same specification, and quality. The length difference ($l_1 - l_2$) of the two pieces of cables shall be at least 3 m. Both TS shall be made by the same methods.

To improve test accuracy, it is recommended that the connectors at both ends of the TS are threaded RF coaxial connectors pair which can connect VNA directly.

7.3.2 Test procedure

The test procedure shall be as follows.

a) After VNA is fully preheated, set the measurement frequency range and the test mode to S12 or S21. The number of scanning points shall be set according to Formula (3) by using the longer cable length of the TS and should not be less than 801 points. When the value calculated according to Formula (3) exceeds the maximum number of points of the device, the highest number of points that the device can reach should be taken.

b) System calibration: full two port calibration shall be performed at the ends of the test cables.

c) Connect the longer TS to the test port of VNA. Measure its insertion loss noted as $IL_1(f)$.

d) Remove the longer TS and connect the shorter TS to the test port of VNA. Measure its insertion loss noted as $IL_2(f)$.

e) Calculate the attenuation constant of the TS by using Formula (5):

$$\alpha(f) = \frac{100 \times [IL_1(f) - IL_2(f)]}{l_1 - l_2} \tag{5}$$

where

α is the attenuation constant, dB/100 m;

$IL_1(f)$ is the insertion loss of the longer TS, dB;

$IL_2(f)$ is the insertion loss of the shorter TS, dB;

l_1 is the length of the longer TS in metres, m;

l_2 is the length of the shorter TS in metres, m.

8 Temperature correction

When the relevant specification or the user requires the attenuation constant of a cable at 20 °C, the measured attenuation constant shall be corrected to the value at 20 °C by using Formula (6):

$$\alpha_{20}(f) = \frac{\alpha_T(f)}{1 + {K}/{100} \cdot (T - 20)} \tag{6}$$

where

K is the correction factor. Correction factor K shall be defined in the relevant cable specification (e.g. for copper, coaxial with non-polar insulation K = 0,2 %/ °C);

T is the temperature during the measurement, °C;

$\alpha_T(f)$ is the attenuation constant at ambient temperature during measurement, dB/100 m;

$\alpha_{20}(f)$ is the attenuation constant at 20 °C by temperature correction, dB/100 m.

9 Fitting of the attenuation constant formula

If multiple reflections occur at low frequencies due to a mismatch between the test specimen and the test set-up, the attenuation curve shows ripples. In that case, a form fitting is needed to smooth the curve, and the measured attenuation of the cable shall be fitted by Formula (7):

$$\alpha_{\text{fit}}(f) = A \cdot \sqrt{f} + B \cdot f + \frac{C}{\sqrt{f}} + D \tag{7}$$

where

$\alpha_{\text{fit}}(f)$ is the fitted attenuation of the cable temperature corrected attenuation $\alpha_{20}(f)$.

A is the loss coefficient of inner and outer conductors caused by skin effect;

B is the dielectric loss coefficient;

C is the optional coefficient for copper clad conductor loss;

D is the constant component;

f is the frequency.

The form fitting shall be a least square fitting done on the corrected attenuation values $\alpha_{20}(f)$.

The least square fit coefficients are calculated using Formula (8):

$$\begin{vmatrix} A \\ B \\ C \\ D \end{vmatrix} = \begin{vmatrix} \sum_{i=1}^{N} f_i & \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{1/2} & N \\ \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{2} & \sum_{i=1}^{N} f_i & \sum_{i=1}^{N} f_i^{1/2} \\ \sum_{i=1}^{N} f_i^{1/2} & \sum_{i=1}^{N} f_i & N & \sum_{i=1}^{N} f_i^{-1/2} \\ N & \sum_{i=1}^{N} f_i^{1/2} & \sum_{i=1}^{N} f_i^{-1/2} & \sum_{i=1}^{N} f_i^{-1} \end{vmatrix}^{-1} \times \begin{vmatrix} \sum_{i=1}^{N} \alpha_{20,i} \times f_i^{1/2} \\ \sum_{i=1}^{N} \alpha_{20,i} \times f_i \\ \sum_{i=1}^{N} \alpha_{20,i} \\ \sum_{i=1}^{N} \alpha_{20,i} \times f_i^{1/2} \end{vmatrix} \tag{8}$$

where

A, B, C, D	are the the least square fit coefficients;
f_i	is the frequency at measurement point i;
N	is the number of measured frequency points;
$\alpha_{20,i}$	is the temperature corrected attenuation at measurement point i.

If the inner conductor of the cable is a non-copper-clad conductor, then D = 0; the least square fitting coefficient can be calculated using Formula (9):

$$\begin{vmatrix} A \\ B \\ C \end{vmatrix} = \begin{vmatrix} \sum_{i=1}^{N} f_i & \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{1/2} \\ \sum_{i=1}^{N} f_i^{3/2} & \sum_{i=1}^{N} f_i^{2} & \sum_{i=1}^{N} f_i \\ \sum_{i=1}^{N} f_i^{1/2} & \sum_{i=1}^{N} f_i & N \end{vmatrix}^{-1} \times \begin{vmatrix} \sum_{i=1}^{N} \alpha_{20,i} \times f_i^{1/2} \\ \sum_{i=1}^{N} \alpha_{20,i} \times f_i \\ \sum_{i=1}^{N} \alpha_{20,i} \end{vmatrix} \tag{9}$$

10 Requirements

The attenuation constants at different frequencies should not exceed the values specified in the relevant detailed specifications.

11 Test report

The test report should include following information:

a) test conditions;
b) test method;
c) test equipment;
d) sample code and length;
e) test frequency range;
f) measurement of the number of frequency points;
g) attenuation constant at different frequencies;
h) fitting of the recorded attenuation constant function or curve when required;
i) operator name and test date.

Annex A
(normative)

Stability of attenuation constant at different temperatures

A.1 Purpose

This test is to determine the stability of attenuation constant by testing the attenuation constant of coaxial cable at different temperatures.

A.2 Stability of attenuation constant at different temperatures

The stability of attenuation constant at different temperatures is the changing ratio of attenuation constants at different temperatures relative to its attenuation constant at 20 °C, expressed by Formula (A.1):

$$\delta\alpha(f) = \frac{\alpha_{t,f} - \alpha_{20℃,f}}{\alpha_{20℃,f}} \times 100\ \% \qquad \text{(A.1)}$$

where

$\delta\alpha(f)$ is the stability of the attenuation constant at each temperature point at the frequency f;

$\alpha_{t,f}$ is the attenuation constant at each measured temperature point at the frequency f, dB/100 m;

$\alpha_{20\ °C,\ i}$ is the attenuation constant at 20 °C at the frequency f, dB/100 m.

A.3 Preparation to test sample (TS)

Unless otherwise specified, cut two pieces of cables with different lengths from a cable under test; each piece of cable shall be connected to a pair of connectors to form a cable assembly as test sample (TS). The two pairs of connectors shall be the same mode specification and quality.

To improve test accuracy, it is recommended that the connectors at both ends of the TS are threaded RF coaxial connectors pair which can connect VNA directly.

The length difference ($l_1 - l_2$) between the two pieces of cables shall be at least 3 m. Both TS shall be made by the same methods. Mark each TS at a distance of 0,3 m from both ends, as shown in Figure A.1.

Dimensions in metres

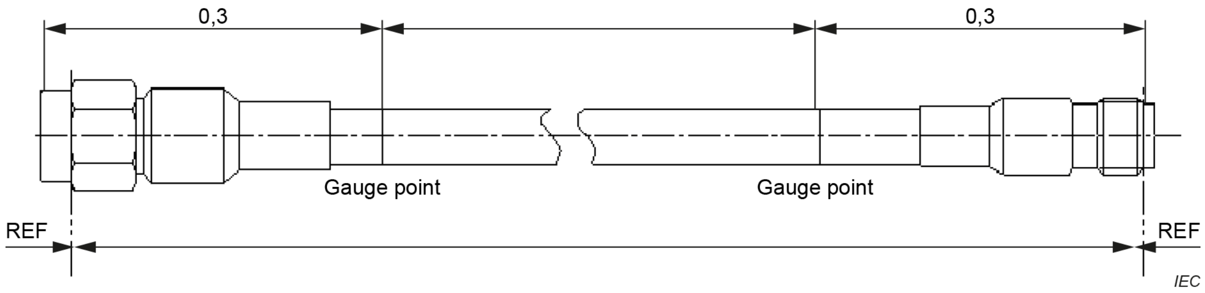

Figure A.1 – Preparation of TS for stability of attenuation constant

A.4 Test equipment

The test equipment shall be as follows:

a) temperature test chamber: the temperature control accuracy is ±2 °C or meets the relevant detailed specifications, and the temperature range and volume can meet the relevant detailed specifications;

b) a vector network analyser with sufficient precision.

A.5 Test environment

The change range of laboratory ambient temperature t_0 should be kept within ±2 °C.

For cables with PTFE dielectric, the laboratory ambient temperature t_0 should avoid the material sensitive temperature range.

A.6 Test procedure

The test procedure shall be as follows.

a) Put two TS into the temperature test chamber with their two ends stretching out of the chamber from the gauge points. Then seal the test chamber with heat insulation plug as shown in Figure A.2. Other parts of TS should be loosely wound into a diameter of not less than 10 times the minimum static bending radius of the cable, and placed in a suitable position in the temperature test chamber to ensure that the cable is evenly heated.

Dimensions in metres

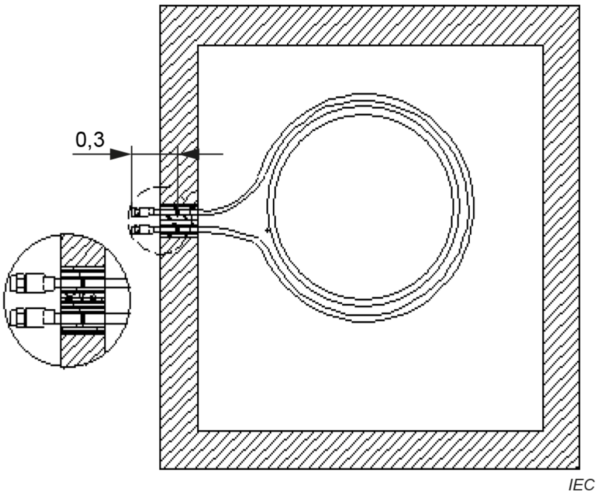

Figure A.2 – Schematic diagram of TS placement

It is recommended to place the marks in the middle of the heat insulation plug.

b) After VNA is fully preheated, set the measurement frequency range and the test mode to S12 or S21.The number of scanning points shall be set according to Formula (3) by using the longer cable length of the TS and should not be less than 801 points. When the value calculated according to Formula (3) exceeds the maximum number of points of the device, the highest number of points that the device can reach should be taken.

c) System calibration: full two port calibration shall be performed at the ends of the test cables.

d) Adjust the temperature of the test chamber to 20 °C and keep 20 °C at least 30 min or according to relevant detailed specifications. Connect the longer TS to the test port of VNA. Measure its insertion loss noted as $IL_{1,20\ °\mathrm{C},f}$. Use the same way to measure insertion loss of the short TS noted as $IL_{2,20\ °\mathrm{C},f}$.

e) Adjust the temperature of the test chamber to T °C and keep T °C at least 30 min or according to relevant detailed specifications and repeat d) to measure the insertion losses $IL_{1,T,f}$ of the longer TS and $IL_{2,T,f}$ of short TS respectively. T are the measurement temperatures specified in the relevant detailed specification and which, during the test temperatures, shall be from low to high.

A.7 Test results

The stability of the attenuation constant $\delta\alpha(f)$ at each temperature point T at the same frequency shall be calculated according to Formula (A.2):

$$\delta\alpha(f) = \frac{100\times\left(IL_{1,T,f}-IL_{2,T,f}\right)\Big/ l_1-l_2 - 100\times\left(IL_{1,20°\mathrm{C},f}-IL_{2,20°\mathrm{C},f}\right)\Big/ l_1-l_2}{100\times\left(IL_{1,20°\mathrm{C},f}-IL_{2,20°\mathrm{C},f}\right)\Big/ l_1-l_2}\times 100\ \%$$

$$= \frac{\left(IL_{1,T,f}-IL_{2,T,f}\right)-\left(IL_{1,20°\mathrm{C},f}-IL_{2,20°\mathrm{C},f}\right)}{IL_{1,20°\mathrm{C},f}-IL_{2,20°\mathrm{C},f}}\times 100\ \% \qquad \text{(A.2)}$$

where

$\delta a(f)$ is the stability of the attenuation constant at each temperature point at the frequency;

l_1 is the length of the longer TS, m;

l_2 is the length of the shorter TS, m;

$IL_{1,\mathrm{T},f}$ is the insertion loss of the longer TS at temperature T at the frequency f, dB;

$IL_{2,\mathrm{T},f}$ is the insertion loss of the shorter TS at temperature T at the frequency f, dB;

$IL_{1,20\ °\mathrm{C},f}$ is the insertion loss of the longer TS at temperature 20 °C at the frequency f, dB.

$IL_{2,20\ °\mathrm{C},f}$ is the insertion loss of the shorter TS at temperature 20 °C at the frequency f, dB.

A.8 Requirements

The stability of the attenuation constant shall comply with the relevant detailed specifications.