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INTERNATIONAL STANDARD

colour inside

Coaxial communication cables –
Part 1-111: Electrical test methods – Stability of phase test methods

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FOREWORD

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International Standard IEC 61196-1-111 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.

The text of this standard is based on the following documents:

FDIS	Report on voting
46A/1188A/FDIS	46A/1212/RVD

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

This second edition cancels and replaces the first edition published in 2005. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

– a new Clause 4 Phase variation with temperature;
– a new Clause 6 Phase stability with bending;
– a new Clause 7 Phase stability with twisting.

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

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 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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COAXIAL COMMUNICATION CABLES –

**Part 1-111: Electrical test methods –
Stability of phase test methods**

1 Scope

This part of IEC 61196 applies to coaxial communication cables. It specifies methods for determining the stability of phase of coaxial communication cables.

- phase variation with temperature (Clause 4);
- phase constant variation with temperature (Clause 5);
- phase stability with bending (Clause 6);
- phase stability with twisting (Clause 7).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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: Generic specification – General, definitions and requirements*

IEC 61196-1-108:2011, *Coaxial communication cables – Part 1-108: Electrical test methods – Test for characteristic impedance, phase and group delay, electrical length and propagation velocity*

3 Terms and definitions

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

3.1
temperature coefficient of phase
$\eta_{t,f}$
coefficient defined at the specified frequency *f*, as the ratio of the phase difference $\Delta\varphi_{t,f}$ between $\varphi_{25\ ^\circ\mathrm{C},f}$ at 25 °C and $\varphi_{t,f}$ at temperature t, and the total phase $\Phi_{25\ ^\circ\mathrm{C},f}$ at 25 °C

$$\eta_{t,f} = \frac{\varphi_{25℃,f} - \varphi_{t,f}}{\Phi_{25℃,f}} = \frac{\Delta\varphi_{t,f}}{\Phi_{25℃,f}} \quad (1)$$

where

$\varphi_{t,f}$ is the phase at temperature t and frequency *f*, in (°);

$\varphi_{25\ ^\circ\mathrm{C},f}$ is the phase at 25 °C and frequency *f*, in (°);

$\Delta\varphi_{t,f}$ is the phase difference between $\varphi_{25\ ^\circ\mathrm{C},f}$ and $\varphi_{t,f}$ at frequency *f*, in (°);

$\Phi_{25\,°C,f}$ is the total phase at 25 °C and frequency f, in (°);

3.2
maximum variation of temperature coefficient of phase
$\left|\Delta\eta\right|_{max}$
maximum value η_{max} minus the minimum value η_{min}

$$\left|\Delta\eta\right|_{max} = \left|\eta_{max} - \eta_{min}\right| \tag{2}$$

3.3
ratio of relative temperature coefficient of phase
PT
ratio of the relative temperature coefficient of phase PT, when the relationship between phase and temperature is sufficiently linear

$$PT = \frac{\left|\varphi_{t_1,f} - \varphi_{t_2,f}\right|}{\Phi_{25℃,\,f} \cdot (t_2 - t_1)} \tag{3}$$

where

$\varphi_{t_1,f}$ is the phase value at t_1 and frequency f, in (°);

$\varphi_{t_2,f}$ is the phase value at t_2 and frequency f, in (°);

$\Phi_{25\,°C,f}$ is the total phase at 25 °C and frequency f, in (°).

t_1 and t_2 are any two temperatures within a specified temperature range in which the relationship between phase and temperature is sufficiently linear ($t_2 > t_1$), in °C.

3.4
total relative variation of phase constant
total relative variation of the phase constant

$$\delta\beta = \frac{\beta_2 - \beta_1}{\beta_{nom}} \tag{4}$$

$$\delta\beta = \frac{l_{e,2} - l_{e,1}}{l_{mech}} \cdot v_{r,nom} = \left(\tau_{p,2} - \tau_{p,1}\right) \cdot c \cdot v_{r,nom} \tag{5}$$

where

β_1 is the phase constant at temperature t_1 in radians/m;

β_2 is the phase constant at temperature $t_2 > t_1$, in radians/m;

β_{nom} is the nominal phase constant in radians/m;

$\tau_{p,1}$ is the phase delay at temperature t_1 in s/m;

$\tau_{p,2}$ is the phase delay at temperature $t_2 > t_1$, in s/m;

c is the propagation velocity in free space (3×10^8 m/s);

$l_{e,1}$ is the electrical length at temperature t_1 in m;

$l_{e,2}$ is the electrical length at temperature $t_2 > t_{1,}$ in m;

l_{mech} is the mechanical length in m;

$v_{r,nom}$ is the nominal relative propagation velocity.

Note 1 to entry: For unidirectional variation, t_1 and t_2 are the limits of a specified temperature range. In the case of changing signs of variation, $t_1$and t_2 become the temperatures at which the extreme value of l_e or τ_p occur.

3.5
temperature coefficient of phase constant
CT
temperature coefficient of the phase constant

$$CT = \frac{\delta\beta}{t_2 - t_1} \text{ in k}^{-1} \tag{6}$$

where

$\delta\beta$ is the total relative variation of the phase constant;

t_1 and t_2 are any two temperatures within a specified range in which the phase constant is approximately linear.

4 Phase variation with temperature

4.1 Purpose

Phase of cable varies as a function of temperature. The temperature variation will induce the change of the dielectric constant ε_r , mechanical length, material character which will cause its phase variation. This variation can be unidirectional or multidirectional. The phase variation is characterized by the temperature coefficient of phase $\eta_{t,f}$, or by the ratio of relative temperature coefficient of phase PT when the relationship between phase and temperature is sufficiently linear. This method provides a test method to determine the phase variation with temperature. The maximum variation of temperature coefficient of phase $\left|\Delta\eta\right|_{\max}$ is given in Formula (2).

4.2 Equipment

A temperature chamber with sufficient precision, temperature range and volume shall meet the requirement specified in the relevant specification (for PTFE insulated cable, the temperature should be within ±2 °C).

A vector network analyzer (VNA) capable of sufficient precision is recommended.

4.3 Test sample

The cable under test shall be terminated with suitable connectors at each end, as shown in Figure 1. It is suggested that a pair of screw thread connectors which suit with the vector network analyzer should be used to make a test sample for convenience and higher precision. Two marks should be made at each end of the test sample, as shown in Figure 1. $L_{1\text{mech}}$ shall not be less than 0,15 m and $L_{2\text{mech}}$ of the cable under test (CUT) shall not be less than 2,70 m.

At least two test samples (short named TS) should be made.

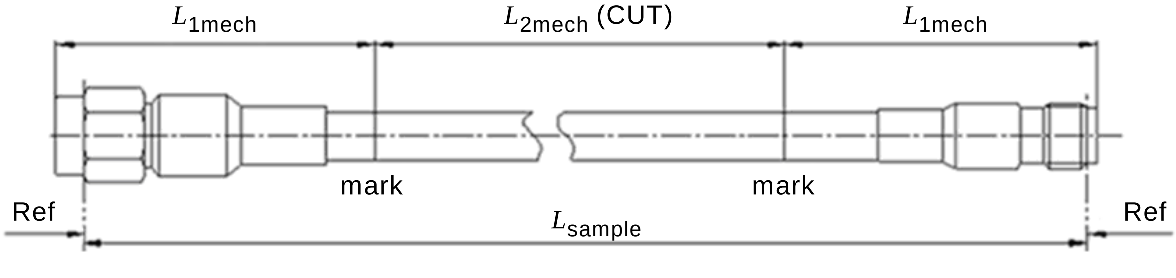


Figure 1 – Test sample (TS)

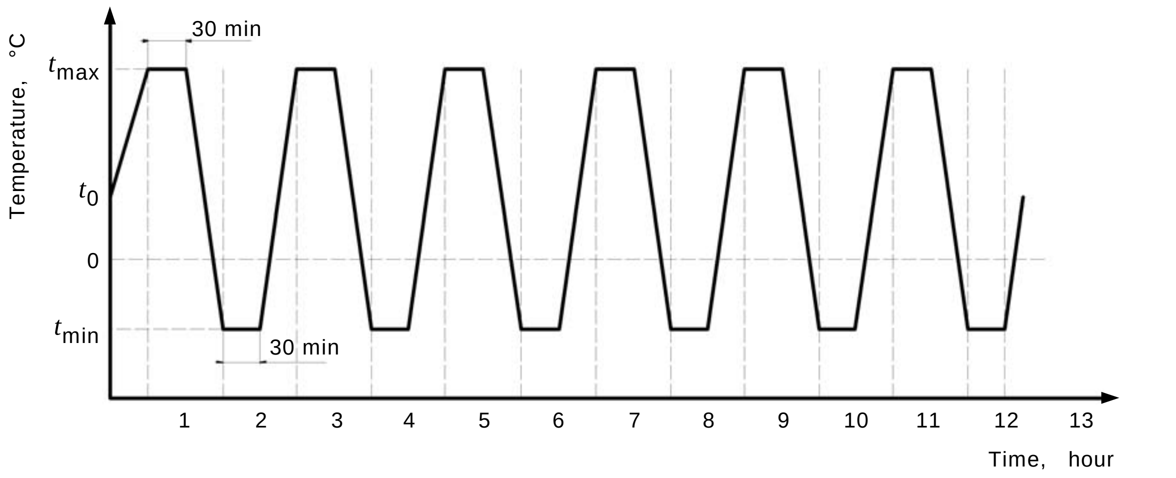
4.4 Test environment

The variation of the laboratory's ambient temperature shall be within ±2 °C. The recommended temperature is 25 °C. For the cable with PTFE dielectric, the laboratory's ambient temperature should avoid the material's sensitive temperature interval.

4.5 Preconditioning

TS shall be put into a temperature chamber in loose coils with the diameter not less than 10 times the cable's minimum static bending radius.

Adjust temperature of the chamber for 6 cycles as shown in Figure 2 and maintain at least 30 min at each limit temperature (t_{max} and t_{min}) which shall be specified in the relevant specification to ensure temperature balance inside. Number of cycles may be agreed between the customer and the supplier.



Key

t_0 laboratory's ambient temperature, for example 25 °C ± 2 °C

t_{max} maximum temperature specified in the relevant specification, in °C

t_{min} minimum temperature specified in the relevant specification, in °C

Figure 2 – Preconditioning

4.6 Test procedure

After preconditioning, one of the TS is picked up for calibration as a reference sample during test. The state and position of the reference sample shouldn't be changed during the test period to avoid the measurement error.

Put the other TS into the temperature chamber with two ends of TS from the marks outside the chamber and seal the chamber with thermal insulating plugs as shown in Figure 3. The marks in Figure 3 are proposed to be placed in the middle of the thermal insulating plugs. The other part (CUT) of the TS in the chamber shall be placed in loose coils with the diameter not less than 10 times the cable's minimum static bending radius.

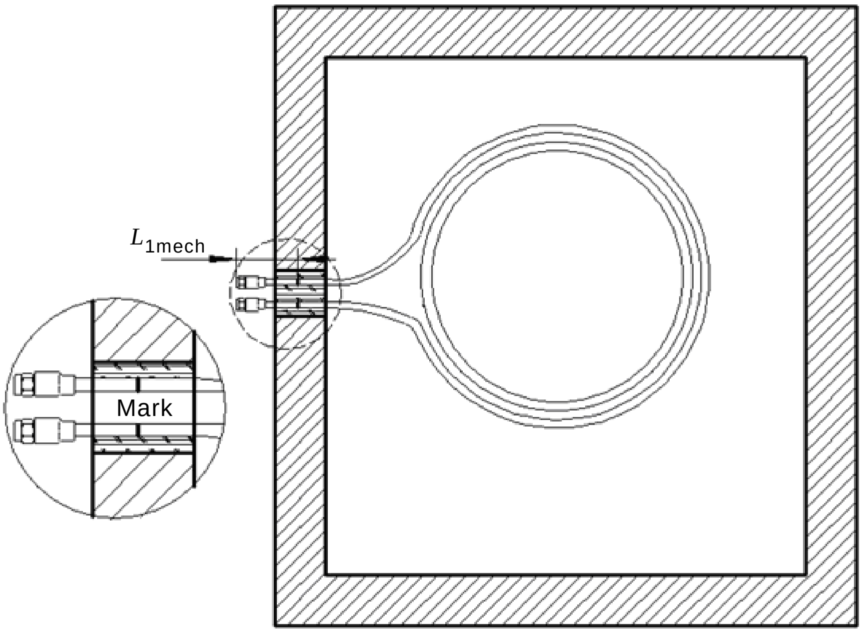


Figure 3 – TS placement diagram

After being preheated, the VNA shall be set to S_{12} or S_{21} with the number of scanning points not less than 801. Calibrate it over the specified frequency range.

Set the temperature chamber to 25 °C and maintain 10 min at least when it reaches the temperature. Connect TS with the VNA, and read the frequency f_1 and f_2 which are the adjacent peak wave or valley wave as shown in Figure 4. f_1 and f_2 should be near the value of f. The total phase of the CUT at frequency f at 25 °C is:

$$\Phi_{25\,°\mathrm{C},f} = 360^\circ \times \frac{f}{f_2 - f_1} \times \frac{L_{2mech}}{L_{sample}} \tag{7}$$

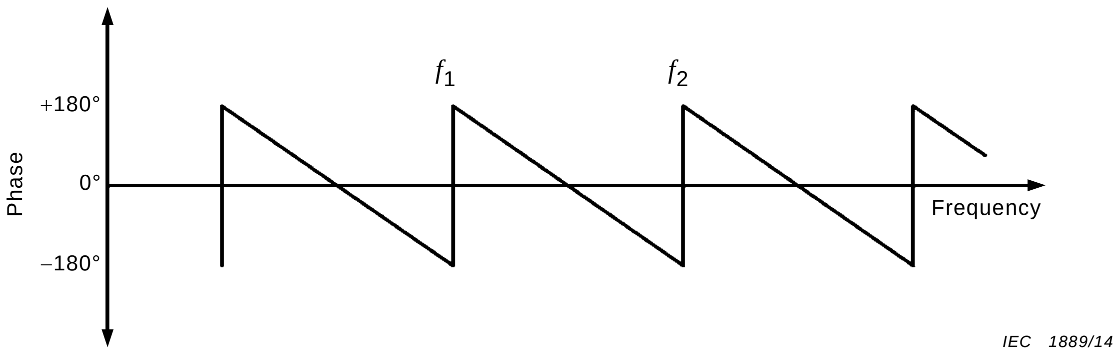


Figure 4 – Phase–frequency graph schematic diagram

At 25 °C, use the reference sample to calibrate VNA. Then connect TS with the VNA and record the phase value $\varphi_{25℃,f}$ at frequency f. Connect the reference sample with the VNA again and record its phase drift $\delta_{25℃,f}$.

Adjust the temperature of the chamber to the lowest temperature t_1 and maintain for enough time so that the CUT get balanced in temperature (see Note 1). Repeat the steps of 4.6 paragraph 5 and record the phase value $\varphi_{t_1,f}$ and phase drift $\delta_{1,f}$ at test frequency f at t_1.

Adjust the temperature of the chamber to each higher temperature t_i (see Note 2) until to the maximum temperature of the cable and repeat the steps of 4.6 paragraph 6 and record the phase value $\varphi_{t_i,f}$ and phase drift $\delta_{i,f}$ at frequency f at t_i.

NOTE 1 Different cables differ in maintaining time. When the outer diameter of cables is less than 6 mm, the maintaining time is at least 30 min or as specified in the relevant specification; when the outer diameter of cables is more than 6 mm, the maintaining time is increased or as specified in the relevant specification.

NOTE 2 For cables with PTFE dielectric, the testing temperature point between –20 °C to 25 °C is increased so as to get a more accurate result.

4.7 Test result

4.7.1 Calculation of temperature coefficient of phase

Use Formula (1) to calculate the temperature coefficient of phase $\eta_{ti,\ f}$ at t_i at frequency f:

$$\eta_{t_i,f} = \frac{\varphi_{25℃,f} - \varphi_{t_i,f} - \delta_{i,f}/2}{\Phi_{25℃,f}} = \frac{\Delta\varphi_{t_i,f}}{\Phi_{25℃,f}} \tag{8}$$

where

$\varphi_{25℃,f}$ is the phase at 25 °C at frequency f, in (°);

$\varphi_{t_i,f}$ is the phase at t_i at frequency f, in (°);

$\delta_{i,f}$ is the VNA phase drift at each temperature point during test, in (°);

$\Phi_{25℃,f}$ is the total phase at 25 °C and frequency f, in (°);

$\Delta\varphi_{t_i,f}$ is the phase difference between $\varphi_{25℃,f}$ and $\varphi_{t_i,f}$ at frequency f, in (°).

The phase drift of the VNA can be ignored when no higher precision is requested, and the temperature coefficient of phase $\eta_{t_i,f}$ at t_i at frequency f can be calculated with:

$$\eta_{t_i,f} = \frac{\varphi_{25℃,f} - \varphi_{t_i,f}}{\Phi_{25℃,f}} = \frac{\Delta\varphi_{t_i,f}}{\Phi_{25℃,f}} \tag{9}$$

4.7.2 Graph of phase temperature change

Use each $\eta_{t_i,f}$ and t_i to draw the $\eta_{t,\ f}$ – T (°C) curve of phase variation with temperature at specified frequency f.

4.7.3 Maximum variation value of phase variation with temperature

Use Formula (2) to calculate maximum variation value of phase variation with temperature ($\eta_{\max} - \eta_{\min}$).

4.7.4 Ratio of the relative phase temperature coefficient

Use Formula (3) to calculate the ratio of the relative phase temperature coefficient PT when the relationship between phase and temperature is sufficiently linear.

4.8 Test report

The test report shall include:

- the preconditioning temperature ($t_{\mathrm{max}} - t_{\mathrm{min}}$);
- the temperature range and test temperature points;
- the maintaining time at each temperature;
- the sample length;
- the test frequency.

Annex A gives an example on how to record the testing data and calculate testing result of the phase variation as temperature change.

4.9 Requirement

The values shall meet the requirements of the relevant specification.

5 Phase constant variation with temperature

5.1 Purpose

Phase constant varies as a function of temperature. This variation can be unidirectional or multidirectional. The stability of the phase constant is characterized either by the total variation of the phase constant or by the temperature coefficient of the phase constant in a temperature range in which the relationship between phase and temperature is sufficiently linear. The phase-temperature relationship of new cables may be influenced by irreversible variations of the phase constant. These can be reduced by heat cycling.

In addition to the temperature, the phase constant depends on the pressure and the humidity of the gas enclosed within the cable. This is of particular interest in the case of cables with airtight outer conductors.

5.2 Equipment

A temperature chamber with sufficient precision, temperature range and volume shall meet the requirement in the relevant specification.

A vector network analyzer (VNA) capable of sufficient precision is recommended.

5.3 Test sample

Prepare TS according to 4.3 or the relevant specification.

5.4 Test environment

The variation of the laboratory's ambient temperature shall be within ±2 °C. For the cable with PTFE dielectric, the laboratory's ambient temperature should avoid the material's sensitive temperature interval.

5.5 Preconditioning

TS shall be preconditioned according to 4.5.

5.6 Test procedure

The VNA shall be calibrated according to the error correction procedure given in the manual of the VNA.

Put the TS into the temperature chamber with two ends of TS from the marks outside the chamber and seal the chamber with thermal insulating plugs as shown in Figure 3. The other parts of the TS in the chamber shall be placed in loose coils with the diameter not less than 10 times the cable's minimum static bending radius.

Refer to Figure 3 for the placement of TS.

Set the temperature of chamber to t_1 and maintain 30 min at least when it reaches t_1. Measure the phase $\varphi_{t_1,f}$ in radians at t_1 according to IEC 61196-1-108.

Set the temperature of chamber to t_2 and maintain 30 min at least when it reaches t_2. Measure the phase $\varphi_{t_2,f}$ in radians at t_2 according to IEC 61196-1-108.

5.7 Test result

According to Formula (8) of IEC 61196-1-108:2011, $\beta_{t_2,f}-\beta_{t_1,f}$ is calculated as:

$$\beta_{t_2,f}-\beta_{t_1,f}=\frac{\varphi_{t_2,f}}{L_{2mech}}-\frac{\varphi_{t_1,f}}{L_{2mech}} \qquad (10)$$

where

$\beta_{t_1,f}$ is the phase constant at t_1 at frequency f, in radians/m;

$\beta_{t_2,f}$ is the phase constant at t_2 at frequency f, in radians/m;

$\varphi_{t_1,f}$ is the phase at t_1 at frequency f, in radians;

$\varphi_{t_2,f}$ is the phase at t_2 at frequency f, in radians.

The total relative variation of the phase constant is:

$$\delta\beta = \frac{\beta_{t_2,f} - \beta_{t_1,f}}{\beta_{nom,f}} \tag{11}$$

where

$\beta_{t_1,f}$ is the phase constant at t_1 at frequency f, in radians/m;

$\beta_{t_2,f}$ is the phase constant at t_2 at frequency f, in radians/m;

$\beta_{nom,f}$ is the nominal phase constant at frequency f, in radians/m.

Use Formula (6) to calculate the temperature coefficient of the phase constant CT:

$$CT = \frac{\delta\beta}{t_2 - t_1}$$

5.8 Test report

The test report shall include:

- the preconditioning temperature ($t_{max} - t_{min}$);
- the temperature range ($t_1 - t_2$);
- the maintaining time;
- the sample length;
- the test frequency;
- the nominal phase constant;
- the temperature coefficient of the phase constant.

5.9 Requirement

The values shall meet the requirements of the relevant specification.

6 Phase stability with bending

6.1 Purpose

The structure and electrical length of the cable will be changed when it is subjected to bending, which will induce the phase change. This method provides a test method to determine the phase variation with specified frequency when the cable is subjected to bending.

6.2 Test environment

The variation of the laboratory's ambient temperature shall be within ±2 °C. The recommended temperature is 25 °C.

6.3 Test sample

The cable under test shall be terminated with suitable connectors at each end, as shown in Figure 5. It is recommended that a pair of screw thread connectors which suit with the vector network analyzer is used to make a test sample for convenience and higher precision. The length L of the cable under test (CUT) shall meet the requirements shown in Figure 6.

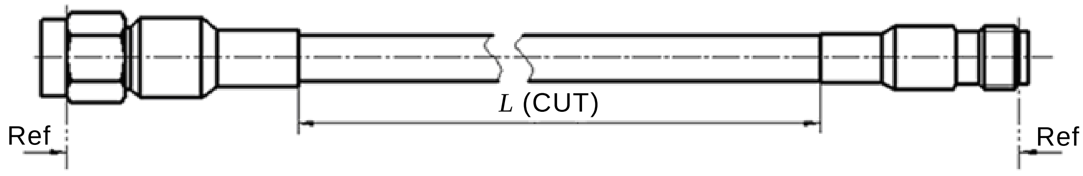


Figure 5 – Test sample (TS)

6.4 Equipment

A vector network analyzer (VNA) capable of sufficient precision is recommended.

Test clamp for fixation should meet the precision requirement (if needed).

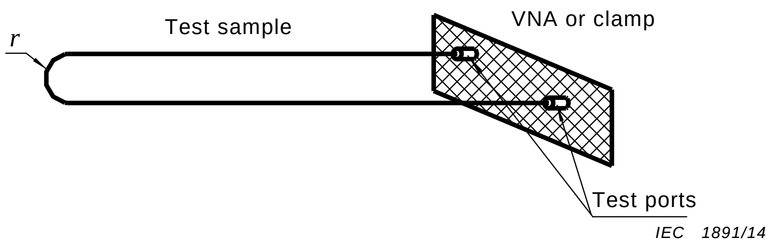
6.5 Test procedure

After being preheated, the VNA shall be set to S12 or S21 with the number of scanning points not less than 801. Calibrate it over the specified frequency range.

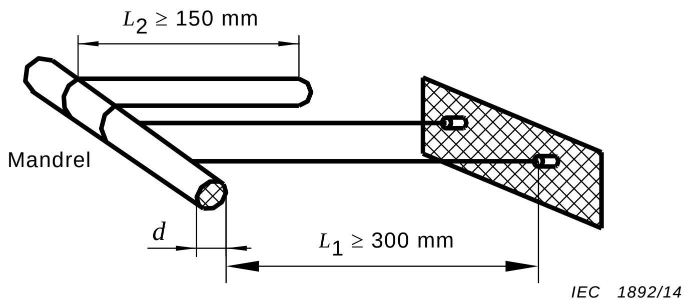
Connect the TS with the VNA and bend the CUT to U shape with the minimum bending radius r specified in relevant specification as shown in Figure 6 a). Calibrate the phase of the VNA to zero.

Put a mandrel with the specified diameter d on C, and bend the CUT around the mandrel for 180° as shown in Figure 6 b). Record curve 1 of the phase variation with frequency in the VNA, shown in Figure 8. Bending should be very carefully performed and stable in order to reduce its effect on the test result.

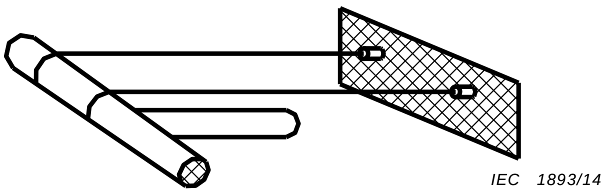
Straighten CUT back to the initial position shown in Figure 6 a). Put the mandrel under the CUT, and then bend the CUT around the mandrel for 180° in a reversed way as shown in Figure 6 c). Record curve 2 of the phase variation with frequency in the VNA shown in Figure 8.



a) Initial position



b) First bend



c) Second bend

Figure 6 – Bending test

6.6 Test report

The test report shall include:

- the bending radius r of the U shape; usually r is not less than the minimum dynamic bending radius;
- the diameter d of the mandrel, which is usually 10 times the cable's outer diameter;
- the test frequency;
- the result of the test: curve 1 and curve 2.

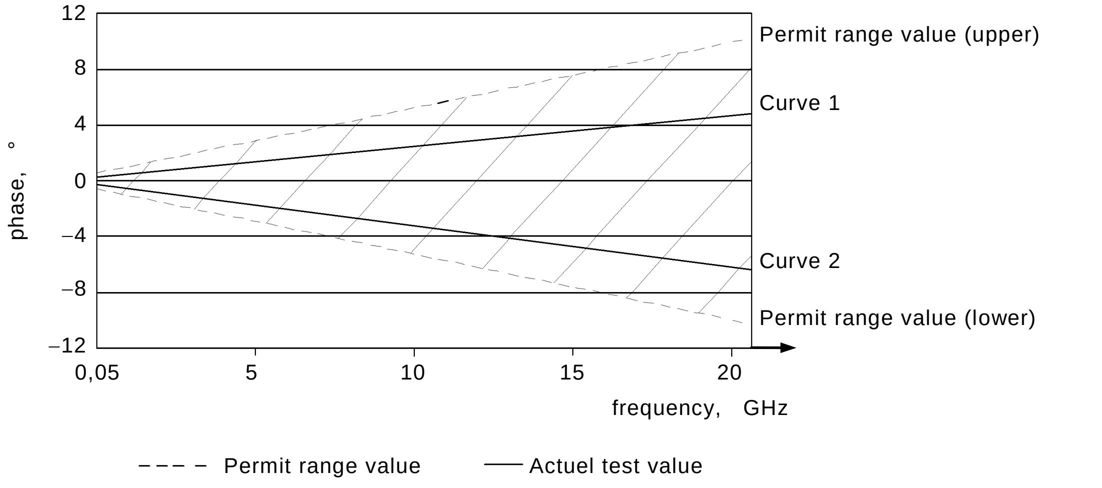


Figure 7 – Test graph schematic diagram

6.7 Requirement

The result of the test (curve 1 and curve 2) shall meet the requirement in the relevant specification shown as permit range value in Figure 7.

7 Phase stability with twisting

7.1 Purpose

The structure and electrical length of the cable will be changed when it is subjected to twisting, which will induce the phase change. This method provides a test method to determine the phase variation with specified frequency when the cable is subjected to twisting.

7.2 Test environment

The variation of the laboratory's ambient temperature shall be within ±2 °C. The recommended temperature is 25 °C.

7.3 Test sample

The cable under test shall be terminated with suitable connectors at each end, as shown in Figure 5. A pair of screw thread connectors which suit with the vector network analyser should be used to make a test sample for convenience and higher precision. The length L of the cable under test should be:

$$L = \frac{360^\circ}{\theta} \tag{12}$$

where

L is the length of CUT, in m;

θ is the permitting maximum twist angle per length specified in the relevant specification, in °/m.

7.4 Equipment

A vector network analyzer (VNA) capable of sufficient precision is recommended.

Test clamp for fixation should meet the precision requirement (if needed).

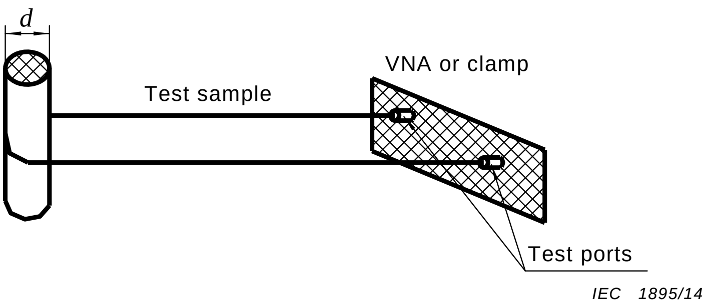
7.5 Test procedure

After being preheated, the VNA shall be set to S_{12} or S_{21} with the number of scanning points not less than 801. Calibrate it over the specified frequency range.

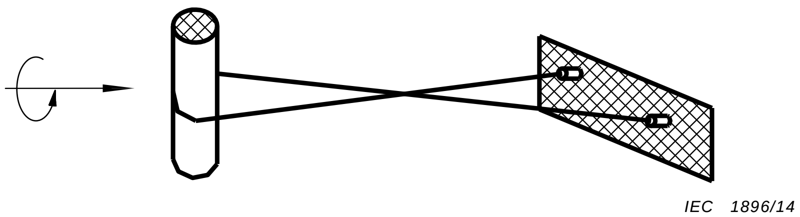
Connect the TS with the VNA and bend the CUT to U shape around a mandrel with the specified diameter d as shown in Figure 8 a). Calibrate the phase of the VNA to zero.

Rotate the mandrel to 180° as shown in Figure 8 b) and record curve 3 of the phase variation with frequency in the VNA shown in Figure 9. Twisting should be very carefully performed and stable in order to reduce its effect on the test result.

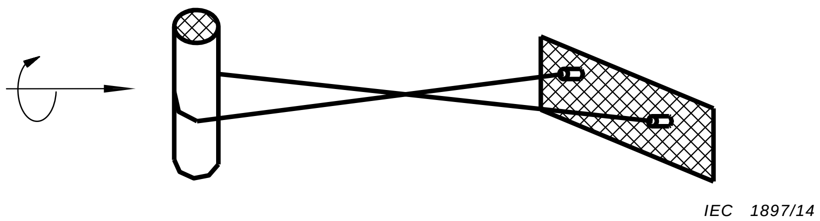
Return the mandrel to the initial position shown in Figure 8 a). Then rotate the mandrel to 180° in the reverse way as shown in Figure 8 c). Record curve 4 of the phase variation with frequency in the VNA shown in Figure 9.



a) Initial position



b) First twist



c) Second twist

Figure 8 – Twist test

7.6 Test report

The test report shall include:

- the diameter d of the mandrel, which is usually 10 times the cable's outer diameter;

- the test frequency range;
- the maximum twist angle per length;
- the result of test: curve 3 and curve 4.

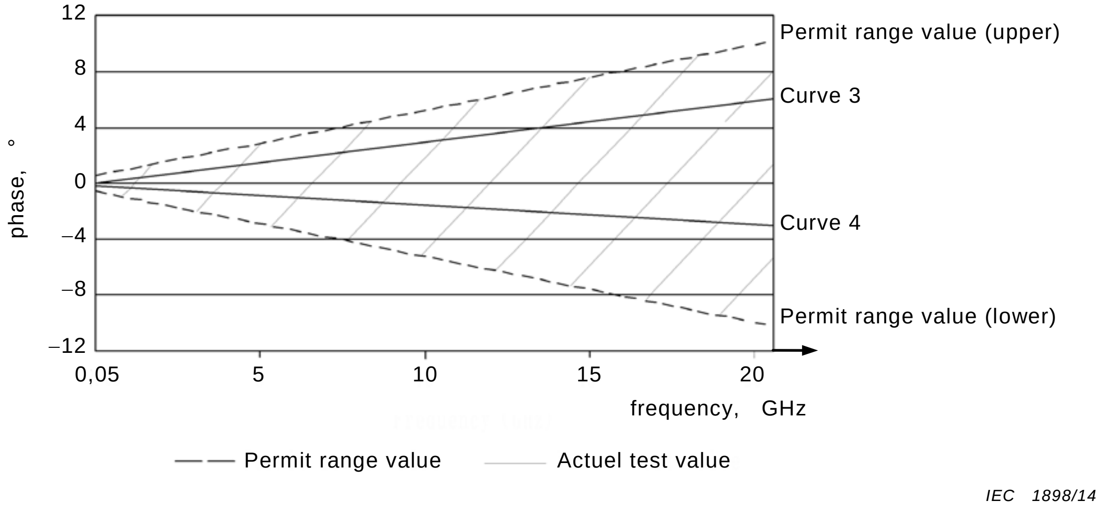


Figure 9 – Test graph schematic diagram

7.7 Requirement

The result of test (curve 3 and curve 4) shall meet the requirements in the relevant specification shown as permit range value in Figure 9.

Annex A
(informative)

Example for recording and calculating the phase variation with temperature

Laboratory's temperature:	25 °C ± 2 °C
Preconditioning temperature:	t_{max}: 100 °C t_{min}: –40 °C
Test sample:	2 pieces of cable of 3 m long and SMA connectors terminated in both ends;
Test frequency f:	5 GHz;
Test temperature points:	–50 °C, –25 °C , 0°C, 15 °C, 20 °C, 25 °C, 50 °C, 75 °C, 100 °C;
Maintaining time:	30 min;
Record:	f_1 = 5,29637 GHz; f_2 = 5,37985 GHz; $\varphi_{25\,°C,f}$ = –106,39°

According to Formula (7):

$$\Phi_{25\,°C,f} = 360° \times \frac{f}{f_2 - f_1} \times \frac{L_{2mech}}{L_{sample}}$$

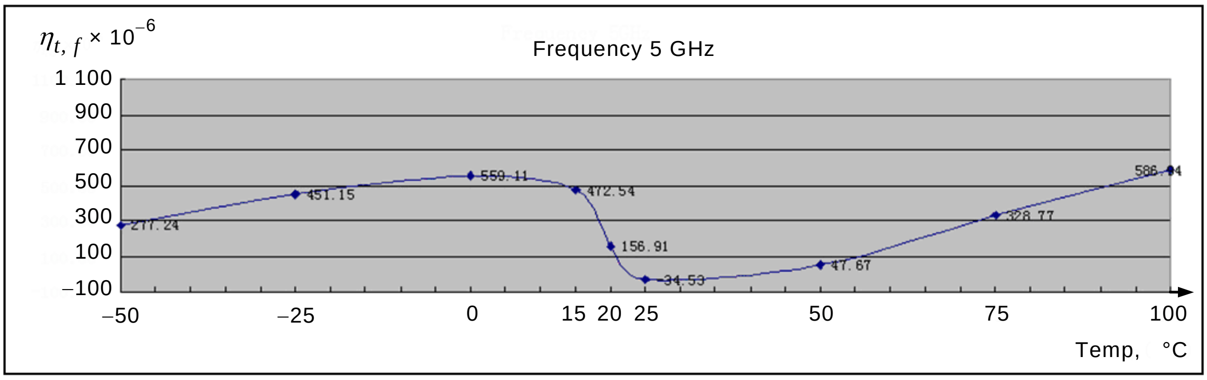
Calculate the total phase $\Phi_{25\,°C,f}$ = 19405,8° at 25 °C;

Calculate the temperature coefficient of phase $\eta_{ti,f}$ at temperature t_i and fill in Table A.1.

Table A.1 – Test record and calculation

No.	t °C	$\varphi_{t_i,f}$ °	$\delta_{i,f}$ °	$\Delta\varphi_{t_i,f} = \varphi_{25℃,f} - \varphi_{t_i,f} - \delta_{i,f}/2$ °	$\eta_{t_i,f} = \frac{\Delta\varphi_{t_i,f}}{\Phi_{25℃,f}}$
0	25	–106,39	0	–	–
1	–50	–111,87	0,20	5,380	277,24 × 10^{-6}
2	–25	–115,23	0,17	8,755	451,15 × 10^{-6}
3	0	–117,32	0,16	10,850	559,11 × 10^{-6}
4	15	–115,64	0,16	9,170	472,54 × 10^{-6}
5	20	–109,52	0,17	3,045	156,91 × 10^{-6}
6	25	–105,78	0,12	–0,670	–34,53 × 10^{-6}
7	50	–107,42	0,21	0,925	47,67 × 10^{-6}
8	75	–112,96	0,38	6,380	328,77 × 10^{-6}
9	100	–118,02	0,48	11,390	586,94 × 10^{-6}

Drawing as below:



IEC 1899/14

Figure A.1 – $\eta_{t,f}$ – T (°C) graph

Test result calculation:

a) maximum phase variation with temperature $\left|\Delta\eta\right|_{\max}$

According to Figure A.1: $\eta_{\max}$: 586,94 × 10^{-6}

$\eta_{\min}$: –34,53 × 10^{-6}

According to Formula (2):

$$\left|\Delta\eta\right|_{\max} = \left|\eta_{\max} - \eta_{\min}\right| = \left|586,94\times10^{-6} - \left(-34,53\times10^{-6}\right)\right| = 621,47\times10^{-6}$$

b) ratio of temperature coefficient with phase PT

According to Figure A.1, the relationship between phase and temperature is linear between 25 °C and 100 °C.

According to Figure A.1: $\varphi_{25\,°\mathrm{C},f}$: –105,78

$\varphi_{100\,°\mathrm{C},f}$: –118,02

According to Formula (3):

$$PT = \frac{\left|\varphi_{25\,°\mathrm{C},f} - \varphi_{100\,°\mathrm{C},f}\right|}{\Phi_{25\,°\mathrm{C},f}\cdot\left(t_2 - t_1\right)} = \frac{\left|-105{,}78 - \left(-118{,}02\right)\right|}{19405{,}8\cdot\left(100 - 25\right)} = 8{,}41\times10^{-6}$$

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