# IEC 61196-1-119

Edition 2.0 2020-05

# INTERNATIONAL STANDARD

**Coaxial communication cables –**
**Part 1-119: Electrical test methods – RF average power rating**



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International Standard IEC 61196-1-119 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.

This second edition cancels and replaces the first edition, published in 2012. This edition constitutes a technical revision.

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

a) title was changed from: RF power rating to: RF average power rating;
b) a test method to determine sufficient duration is included as Annex A;
c) the equations used for calculating cable coefficients and RF average power rating are corrected;
d) the clauses and subclauses are rearranged.

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

| FDIS | Report on voting |
|---|---|
| 46A/1401/FDIS | 46A/1408/RVD |

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

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

A list of all the 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 "http://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- withdrawn,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 1-119: Electrical test methods – RF average power rating

## 1 Scope

This part of IEC 61196 defines the requirements to determine the average power handling capability of a coaxial cable at specified frequencies at ambient temperatures.

## 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: Generic specification – General, definitions and requirements*

IEC 61196-1-113, *Coaxial communication cables – Part 1-113: Electrical test methods – Test for attenuation constant*

## 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 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

**3.1**
**RF average power rating**
maximum average input power that a cable can continuously handle when terminated in its characteristic impedance at a reference ambient temperature (usually 40 °C) and RF frequency

Note 1 to entry: RF average power rating is determined by the power level at which the temperature at any location in the cable does not exceed the allowable maximum temperature rating of the materials used in the cable's construction.

Note 2 to entry: Typically, the inner conductor temperature determines the maximum operating temperature.

Note 3 to entry: The test RF signal is a pure sinusoidal, without any modulation.

## 4 Symbols

For the purposes of this document, the following symbols apply.

$K_i$ thermal constant of the insulation (W/(°C·m))

$K_o$ thermal constant of outer sheath (W/(°C·m))

$A$ attenuation constant associated with the conductors $\left(\frac{\text{dB}}{\text{m}\cdot\sqrt{\text{MHz}}}\right)$

$A_i$ attenuation constant of inner conductor $\left(\frac{\text{dB}}{\text{m}\cdot\sqrt{\text{MHz}}}\right)$

$A_o$ attenuation constant of outer conductor $\left(\frac{\text{dB}}{\text{m}\cdot\sqrt{\text{MHz}}}\right)$

$B$ attenuation constant for the dielectric material $\left(\frac{\text{dB}}{\text{m}\cdot\text{MHz}}\right)$

$a$ mean outer diameter of inner conductor (mm)

Sine shape corrugated: Mean = (peak + root)/2

Other shape corrugated: Mean shall be specified by the manufacturer.

Smooth wall = outer diameter

Wire = outer diameter

$b$ mean inner diameter of outer conductor (mm)

Sine shape corrugated: Mean = (peak + root)/2

Other shape corrugated: Mean shall be specified by the manufacturer.

Smooth wall = inner diameter

$C_i$ corrugation factor of inner conductor:

Ratio of the distance that compares the non-corrugated (conversion of corrugated length to an equivalent smooth wall length) to the cable corrugated length.

$C_i$ > 1 for corrugated cable

$C_i$ = 1 for smooth wall or wire

$C_o$ corrugation factor of outer conductor

Ratio of the distance that compares the non-corrugated (conversion of corrugated length to an equivalent smooth wall length) to the cable corrugated length.

$C_o$ > 1 for corrugated cable

$C_o$ = 1 for smooth wall

$P_{in}$ RF input power (W)

$P_r$ rated RF average power (W) at frequency $f$

$P_{rf1}$ rated RF average power (W) at frequency $f_1$

$P_{rf2}$ rated RF average power (W) at frequency $f_2$

$P_i$ power dissipated in inner conductor (W/m)

$P_o$ power dissipated in outer conductor (W/m)

$\sigma_i$ conductivity of inner conductor (relative to copper)

$\sigma_o$ conductivity of outer conductor (relative to copper)

$\gamma_i$ temperature coefficient of resistance for inner conductor

$\gamma_o$ temperature coefficient of resistance for outer conductor

$\alpha_c$ attenuation of cable, at frequency $f$ (dB/100 m)

$\alpha_{f1}$ attenuation of cable, at frequency $f_1$ (dB/100 m)

$\alpha_{f2}$ attenuation of cable, at frequency $f_2$ (dB/100 m)

$\alpha_i$ attenuation of inner conductor, at frequency $f$ (dB/100 m)

$\alpha_o$ attenuation of outer conductor, at frequency $f$ (dB/100 m)

$T_i$ inner conductor temperature (°C)

$T_o$ outer conductor temperature (°C)

$T_a$ test ambient temperature (°C)

$T_{ri}$ inner conductor temperature rise (°C)

$T_{ro}$ outer conductor temperature rise (°C)

$R_T$ maximum rated ambient temperature (°C)

# 5 Methodology

## 5.1 Method A

If a suitable RF power source is available, it is possible to determine the input power required for a conductor temperature to reach its limiting value (i.e. the RF average power rating), per 7.1. This provides measurements at one frequency and generally needs to be adjusted to other frequencies by knowing the RF cable attenuation.

## 5.2 Method B

Cables of large diameter, however, have high RF average power ratings, and a suitable RF source may not be available for such direct test. The following methodology allows the RF average power rating to be determined by using low frequency (50 Hz or 60 Hz) AC power to determine the cable thermal characteristics first (i.e. the thermal constants $K_i$ and $K_o$). As these parameters are independent with frequency, it can be combined with RF data for RF average power rating calculation. This is because the relative conductor power dissipations are different. Also, there is no dissipation in the dielectric in the low frequency case, but at RF frequencies it becomes significant.

# 6 Test general considerations

## 6.1 Sample preparation

A cable of sufficient length shall be used so that the temperatures measured at the centre of the cable are not influenced by heat sinking effects at the ends of the cable.

## 6.2 Surrounding condition

There shall be sufficient air space around the cable under test to allow natural air circulation.

## 6.3 Temperature test

Temperature measurements on the inner and outer conductors shall be made at the centre of the cable length and 0,5 m away from both sides of the centre point. For RF test – method A, the temperature should be measured at the cable’s current antinode.

The thermocouples should be chosen and sized to eliminate the possibility of heat sinking effects, particularly with thin walled cables.

The test is conducted for sufficient duration for the conductors to reach constant temperatures. A test method to determine sufficient duration is included as Annex A.

## 6.4 Test equipment

For method A, the RF power source, power meter, temperature tester, coupler and absorbing load are needed.

For method B, the AC power source, multimeter and temperature tester are needed.

No matter which method is used, the sufficient power should be applied for a conductor temperature to reach its maximum value, and be determined by the materials used in the cable construction.

The measured results and determination of the average power rating are adjusted for an ambient temperature of 40 °C (or other specified ambient temperature).

# 7 Procedure

## 7.1 RF test – Method A

The input of the cable shall be connected to the RF power source capable of delivering the specified power at the specified test frequency at the load.

The load side of the cable shall be terminated in its characteristic impedance that is capable of handling the power.

The input power, $P_{in}$, at the test frequency shall be monitored.

It is recommended to drill a small hole into the cable just above the inner conductor. A fibre optic thermocouple should be placed within 1 mm above the surface of the inner conductor to measure the temperature.

The input power, at room temperature ($T_a$), shall be increased in stages until maximum component temperature ratings are reached. The conductor temperatures are allowed to stabilize at each stage and then recorded.

Each conductor temperature rise ($T_{ri}$ and $T_{ro}$) at each stage above the room temperature ($T_a$) is determined for each input power level by subtracting the $T_a$ from the measured conductors ($T_i$ or $T_o$) temperature.

For each stage, $T_i$ and $T_o$ shall be determined for $R_T$ by adding $T_{ri}$ and $T_{ro}$ to $R_T$.

Compare the recalculated $T_i$ and $T_o$ at $R_T$ to the maximum temperature ratings of the cable components. The power rating is the level that does not exceed the maximum temperature ratings of the cable components.

The increase in conductor temperature above ambient temperature is determined for each input power level. The average power rating ($P_r$) is that power which will cause an increase in conductor temperature above ambient equal to the difference between the maximum conductor temperature and the reference ambient (usually 40 °C).

The measurement error of $P_r$ should be taken into account when the load is mismatched.

$$e_{max} = 100 \times \left[ \frac{(1+s)^2}{4} - 1 \right] \tag{1}$$

where

$e_{max}$ is the measurement error of $P_r$;

$s$ is the $SWR$ of the DUT.

### 7.2 Low frequency power AC test – Method B

The input of the cable shall be connected to a 50 Hz or 60 Hz source capable of delivering sufficient current carrying capacity.

The opposite cable end shall be short circuited by connecting the inner conductor to the outer conductor.

Adjust the current levels to heat the cable until the cable inner conductor's temperature approaches the maximum insulation operating temperature.

The current, the voltages across both inner and outer conductors and the conductor temperatures (when they have stabilized) shall be measured and recorded. From the voltage and current values, the dissipated powers in the inner and outer conductors ($P_\text{i}$ and $P_\text{o}$) are determined.

The thermal constants $K_\text{i}$ and $K_\text{o}$ are derived from the following equations:

$$P_\text{i} = K_\text{i} \times (T_\text{i} - T_\text{o}) \tag{2}$$

$$P_\text{i} + P_\text{o} = K_\text{o} \times (T_\text{o} - T_\text{a}) \tag{3}$$

An attenuation test shall be conducted in accordance with IEC 61196-1-113 to determine the attenuation at a test ambient at several frequencies over the operating band of the cable. This attenuation response will be used to determine the coefficient for the conductors and dielectric which will then be used in the RF average power calculations at specified frequency or other frequencies.

The $A$ and $B$ coefficients in Formula (4) are calculated by performing a least squares analysis, which is a fit of the measured attenuation and frequency data:

$$\alpha_\text{c} = A \times \sqrt{f} + B \times f \quad \text{(dB/100 m)} \tag{4}$$

where

$A$ is the coefficient for the conductors;

$B$ is the coefficient for the dielectric;

$f$ is the frequency in MHz.

The $A$ and $B$ coefficients are calculated from the attenuation test from the following formulas:

$$A = \frac{\left[\left(\sum_{i=1}^{n} f_i \times \sum_{i=1}^{n}\left(\frac{\alpha_i}{\sqrt{f_i}}\right)\right) - \left(\sum_{i=1}^{n}\sqrt{f_i} \times \sum_{i=1}^{n}\alpha_i\right)\right]}{\left[n \times \sum_{i=1}^{n} f_i - \left(\sum_{i=1}^{n}\sqrt{f_i}\right)^2\right]} \tag{5}$$

$$B = \frac{\left[ n \times \sum_{i=1}^{n} \alpha_i - \left( \sum_{i=1}^{n} \sqrt{f_i} \times \sum_{i=1}^{n} \left( \frac{\alpha_i}{\sqrt{f_i}} \right) \right) \right]}{\left[ n \times \sum_{i=1}^{n} f_i - \left( \sum_{i=1}^{n} \sqrt{f_i} \right)^2 \right]} \quad (6)$$

The $A$ coefficient represents the contribution of the inner and outer conductors. To calculate the power, the conductor inner and outer conductor coefficients ($A_\text{i}$ and $A_\text{o}$) are needed and are determined from the conductivity of the inner and outer conductor. It is determined as follows:

$$A_\text{i} = A \times \frac{\frac{C_\text{i}}{a \times \sqrt{\sigma_\text{i}}}}{\frac{C_\text{i}}{a \times \sqrt{\sigma_\text{i}}} + \frac{C_\text{o}}{b \times \sqrt{\sigma_\text{o}}}} \quad (7)$$

$$A_\text{o} = A \times \frac{\frac{C_\text{o}}{b \times \sqrt{\sigma_\text{o}}}}{\frac{C_\text{i}}{a \times \sqrt{\sigma_\text{i}}} + \frac{C_\text{o}}{b \times \sqrt{\sigma_\text{o}}}} \quad (8)$$

Now, the RF average power rating ($P_\text{r}$) can be determined by solving the following equations numerically (e.g. by using a suitable spreadsheet) for any given frequency and ambient temperature and some limiting value for either inner or outer conductor temperature.

$$P_\text{i} = P_\text{r} \times A_\text{i} \times \sqrt{1 + \gamma_\text{i} \times (T_\text{i} - 20)} \times \frac{\sqrt{f}}{4{,}343} \quad (9)$$

$$P_\text{o} = P_\text{r} \times A_\text{o} \times \sqrt{1 + \gamma_\text{o} \times (T_\text{o} - 20)} \times \frac{\sqrt{f}}{4{,}343} \quad (10)$$

$$P_\text{d} = P_\text{r} \times f \times \frac{B}{4{,}343} \quad (11)$$

$$P_\text{i} + \frac{P_\text{d}}{2} = K_\text{i} \times (T_\text{i} - T_\text{o}) \quad (12)$$

$$P_\text{i} + P_\text{o} + P_\text{d} = K_\text{o} \times (T_\text{o} - T_\text{a}) \quad (13)$$

### 7.3 Adjustment to other frequencies

The following formulas can be used to solve for the average power for either the AC or RF methods.

$$\alpha_{f_2} \times P_{\mathrm{r}_{f_2}} = \alpha_{f_1} \times P_{\mathrm{r}_{f_1}} \qquad (14)$$

or

$$P_{\mathrm{r}_{f_2}} = P_{\mathrm{r}_{f_1}} \times \left( \frac{\alpha_{f_1}}{\alpha_{f_2}} \right) \qquad (15)$$

## 8 Test report

The test report shall include the following:

– method used,
– test conditions,
– test temperature,
– maximum rated operating temperature,
– average power rating determined at specified RF frequencies.

## 9 Requirements

The measured or calculated temperatures shall not exceed the specified temperature ratings of the materials.

# Annex A
(informative)

## Determination method of thermal time constant

### A.1 General

From Definition 3.1, the RF average power rating depends on the maximum operating temperature (the heat generation and dissipation getting in balance) of the cable allowed. Typically, the inner conductor temperature determines the maximum operating temperature, because it always has the highest temperature in the cable construction.

When the power is fed to the cable, due to the influence of the thermal resistance, the cable temperature will not reach steady state immediately. This temperature increase period can be described by Formula (A.1), which shows the relationship between the cable inner conductor's temperature rise and the feeding time.

$$\theta_\tau = \theta(1 - e^{\frac{\tau}{T}}) \quad \text{(A.1)}$$

where

$\theta_\tau$ is the temperature rise of the cable inner conductor at time $\tau$;

$\theta$ is the temperature rise of the cable inner conductor in steady state;

$\tau$ is the feeding time;

$T$ is the thermal time constant.

The thermal time constant has a strong correlation between the thermal resistance and the thermal capacitance. It represents the speed of the cable temperature's change. From Formula (A.1), when feeding time $\tau$ = $3T$, the temperature rise will reach the 95 % of the steady state temperature and can be considered as the approximate value. In general, the easier thermal dissipation is, the larger thermal time constant comes to be.

Based on the significance of thermal time constant in the RF average power rating test, the following clause introduces a determination method of the thermal time constant for coaxial communication cable.

### A.2 Determination method

For Formula (A.1), multiplying both sides by (−1) and re-arranging gives:

$$\theta - \theta_\tau = \theta \cdot e^{-\frac{\tau}{T}} \quad \text{(A.2)}$$

Taking natural logarithm of both sides gives:

$$\ln(\theta - \theta_\tau) = \ln\theta - \frac{\tau}{T} \quad \text{(A.3)}$$