BS EN 61726:2015

BSI Standards Publication

Cable assemblies, cables, connectors and passive microwave components — Screening attentuation measurement by the reverberation chamber method

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National foreword

This British Standard is the UK implementation of EN 61726:2015. It is identical to IEC 61726:2015. It supersedes BS EN 61726:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/46, Cables, wires and waveguides, radio frequency connectors and accessories for communication and signalling.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Cable assemblies, cables, connectors and passive microwave components - Screening attenuation measurement by the reverberation chamber method (IEC 61726:2015)

Câbles, cordons, connecteurs et composants hyperfréquence passifs - Mesure de l'affaiblissement d'écran par la méthode de la chambre réverbérante (IEC 61726:2015)

Konfektionierte Kabel, Kabel, Steckverbinder und passive Mikrowellenbauteile - Messung der Schirmdämpfung mit dem Strahlungskammerverfahren (IEC 61726:2015)

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European Committee for Electrotechnical Standardization
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European foreword

The text of document 46/551/FDIS, future edition 3 of IEC 61726, prepared by IEC/TC 46 "Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61726:2015.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-07-13
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-10-13

This document supersedes EN 61726:2000.

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The text of the International Standard IEC 61726:2015 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC TS 62153-4-1	-	Metallic communication cable test methods - Part 4-1: Electromagnetic compatibility (EMC) - Introduction to electromagnetic screening measurements	-	-
IEC 61000-4-21	-	Electromagnetic compatibility (EMC) -- Part 4-21: Testing and measurement techniques - Reverberation chamber test methods	EN 61000-4-21	-
IEC 61196-1	-	Coaxial communication cables - Part 1: Generic specification - General, definitions and requirements	-	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CABLE ASSEMBLIES, CABLES, CONNECTORS AND PASSIVE MICROWAVE COMPONENTS – SCREENING ATTENUATION MEASUREMENT BY THE REVERBERATION CHAMBER METHOD

FOREWORD

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International Standard IEC 61726 has been prepared by IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

This third edition cancels and replaces the second edition, published in 1999. This edition constitutes a technical revision.

It takes into account the latest developments in the design of reverberation chambers as described in IEC 61000-4-21, which is also referencing this standard as a possible test method. Furthermore, an alternative measurement procedure is added which is able to reduce the measurement time needed.

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

FDIS	Report on voting
46/551/FDIS	46/569/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 publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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.

CABLE ASSEMBLIES, CABLES, CONNECTORS AND PASSIVE MICROWAVE COMPONENTS – SCREENING ATTENUATION MEASUREMENT BY THE REVERBERATION CHAMBER METHOD

1 Scope

The requirements of modern electronic equipment have indicated a demand for a method for testing screening attenuation of microwave components over their whole frequency range. Convenient test methods exist for low frequencies and components of regular shape. These test methods are described in the relevant IEC product specifications (e.g. IEC 62153-4-3). For higher frequencies and for components of irregular shape, a new test method has become necessary and such a test method is described in this International Standard.

This International Standard describes the measurement of screening attenuation by the reverberation chamber test method, sometimes named mode stirred chamber, suitable for virtually any type of microwave component and having no theoretical upper frequency limit. It is only limited toward low frequencies due to the size of the test equipment, which is frequency-dependent and is only one of several methods of measuring screening attenuation.

For the purpose of this standard, examples of microwave components are waveguides, phase shifters, diplexers/multiplexers, power dividers/combiners etc.

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 TS 62153-4-1, *Metallic communication cable test methods – Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic screening measurements*

IEC 61000-4-21, *Electromagnetic compatibility (EMC) – Part 4-21: Testing and measurement techniques – Reverberation chamber test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61196-1 and IEC 61000-4-21 apply.

4 Basic description of the reverberation chamber method

The reverberation chamber method for measurement of the screening attenuation of microwave components consists of exposing the device under test (DUT) to an almost homogeneous and isotropic electromagnetic field and then measuring the signal level induced into the device.

These conditions are achieved by the use of a shielded enclosure, which acts as an oversized cavity (in terms of wavelength), with a high quality factor. Its boundary conditions are continuously agitated by a rotating reflective surface (mode stirrer), mounted within the chamber, which enables the field to approach homogeneous and isotropic conditions during one revolution.

Electromagnetic power is fed to the chamber by means of an input or transmitting antenna. The strength of the field inside the chamber is measured through a reference antenna. The ratio of the injected power (input antenna) to the received power (reference antenna) is the insertion loss of the cavity. The insertion loss is strongly frequency dependent and is also dependent on the quality factor of the cavity. More detailed explanation on the measurement facility can be found in IEC 61000-4-21.

It has been shown that, due to the isotropic field, any antenna placed inside the cavity behaves as if its gain was unity [2][1], therefore no directional effect is to be expected. If the device under test is electrically short, its screening attenuation will be directly related to usual transfer parameters (Z_t and Z_f). If the device under test is not electrically short, the screening attenuation may still be related to Z_t and Z_f in some simple cases (evenly distributed leakage, periodically distributed leakage) using summing functions derived from antenna network theory.

5 Measurement of the screening attenuation of the device under test (DUT)

The measurement of screening attenuation is based on the comparison of the electromagnetic field power outside the DUT to the electromagnetic field power induced into the DUT. The screening attenuation is then defined as:

$$a_s = -10 \log_{10}\left(\frac{P_{DUT}}{P_{REF}}\right) \tag{1}$$

or

$$a_s = -10 \log_{10}\left(\frac{P_{DUT}}{P_{INJ}}\right) - \Delta_{ins} \tag{2}$$

where

P_{DUT} is the power coupled to the device under test (W);

P_{REF} is the power coupled to the reference antenna (W);

P_{INJ} is the power injected into the chamber (W);

Δ_{ins} is the insertion loss of the chamber in decibels (dB).

6 Description of the test set-up

6.1 Reverberation chamber

The used reverberation chamber shall be compliant to IEC 61000-4-21.

In general, a reverberation chamber is a shielded enclosure having any shape. A perfect cubic shape should be avoided for optimum performance at lower frequencies. It shall be made of conductive materials (copper, aluminium or steel) and shall not contain lossy materials. The size of the cavity depends on the lowest test frequency. For a sufficient test facility, a number of at least 100 modes need to be present at this frequency. The upper frequency limit depends

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[1] Figures in square brackets refer to the Bibliography.

on the quality of the shielding enclosure and cables. Furthermore, the sensitivity of the used measurement instruments limits the maximum useable frequency.

6.2 Mode stirrer

The mode stirrer shall be large with respect to wavelength and be bent at angles to the walls of the chamber. The mode stirrer shall be at least two wavelengths from tip to tip at the lowest test frequency.

6.3 Antennas

The reverberation chamber is equipped with input and reference antennas. Both antennas shall present limited resonances in the frequency range and shall not introduce losses; their return loss shall be better than 6 dB.

For convenience, the same antenna should be kept for the whole frequency range. However, strongly polarised and directional antennas may disturb measurements due to lack of isotropic field state. This is checked during the calibration of the reverberation chamber according to IEC 61000-4-21.

6.4 Test equipment

The essential test equipment and components required for an automated screening attenuation measurement are shown in Figure 1. Preamplifiers, amplifiers and other control equipment may also be included in order to improve performance. The generator and the spectrum analyser shall have a common, highly stable frequency reference.

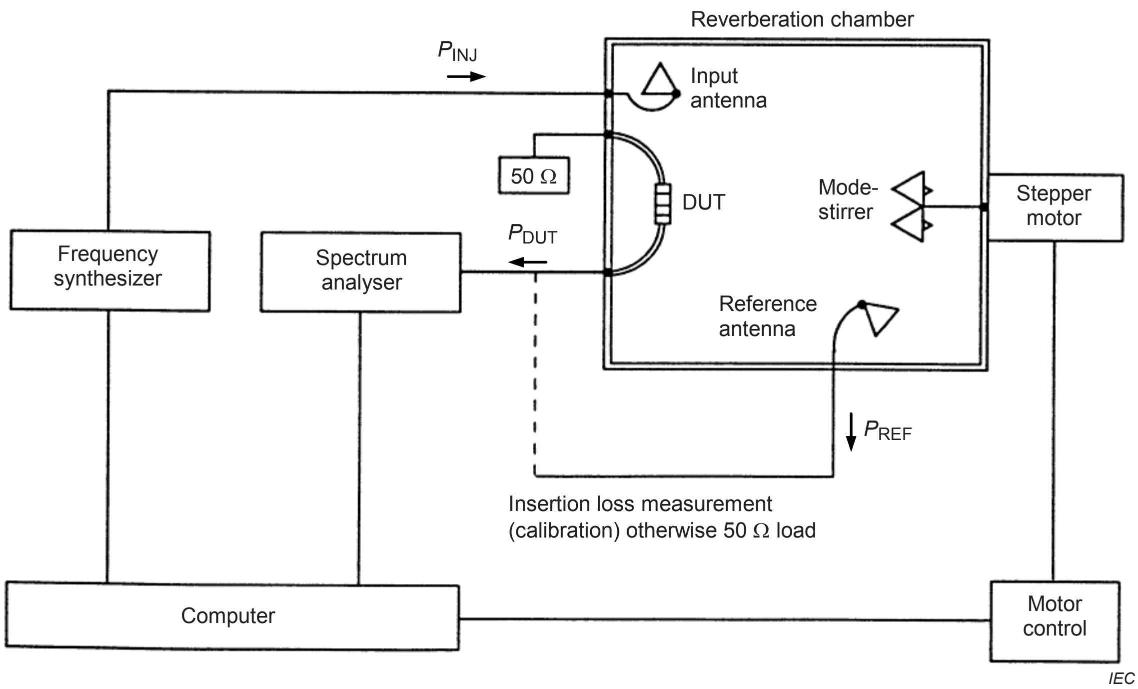


Figure 1 – Example of a test set-up

6.5 Device under test (DUT)

To avoid resonances, the DUT is inserted into a loop (made of semi-rigid coaxial cable) having a length of more than four wavelengths at minimum frequency. The other ports of the DUT should be terminated with matched loads having a screening attenuation at least 10 dB better than the DUT. The assembly is then placed inside the chamber in any orientation and location, the coupling zone being inside the area of homogeneous field according to IEC 61000-4-21.

This is usually the case if a minimum distance from the chamber panels of one wavelength at the lowest frequency is kept. If the DUT is a cable, it shall be ensured that the connectors used are those recommended for the particular type of cable, in order to minimize interface losses. If the cable is to be used in a bent form, than it shall be tested within the limitations imposed by a relevant standard or the manufacturer.

Both ends of the loop are connected to the outputs from the chamber. One end is terminated with a matched load and the other end is connected to the spectrum analyzer. It is also acceptable to terminate the DUT inside the chamber, in which case the second leg of the loop shall be replaced by a single wire, one end being electrically linked to the DUT, the other end to a panel of the chamber.

For the purpose of this method of measurement, waveguides and waveguide accessories (WUT) are not coaxial devices. Therefore, they require to be connected to the appropriate waveguide to coaxial transition(s) in order to be tested in the reverberation chamber.

The measurement of the dynamic range, insertion loss and coaxial calibrator shall be carried out with the waveguide to coaxial transition assembled in the test circuit in the same manner as for the testing of the WUT.

The design of the waveguide to coaxial transitions shall be such that their input and output return loss shall be better than 15 dB. Their design shall ensure that when they are assembled into the test circuit, with a highly screened waveguide in place of the WUT, the total screening effectiveness (dynamic range) shall be at least 10 dB better than the specification for the WUT.

6.6 Linking devices

Linking devices are normally 50 Ω coaxial lines having a screening attenuation at least 10 dB better than the DUT. Depending on practical considerations, semi-rigid or semi-flexible cables may be used.

All linking lines shall be characterized for attenuation at all test frequencies prior to starting the test (attenuators, cable assemblies, etc.).

Equation (2) shall be corrected, taking into account the insertion losses of linking devices:

$$a_s = -10\log_{10}\left(\frac{P_{DUT}}{P_{INJ}}\right) - \Delta_{ins} - X_L \tag{3}$$

where X_L is the insertion loss of all linking devices inside or outside the chamber and is expressed in decibels (dB).

These corrections may be included as part of the test programme for an automated test system. They shall be checked periodically and, at least, during calibration of the test system.

7 Measurement procedure

7.1 General

Different approaches are acceptable depending on the performance of the equipment:

– discrete tuning (step positioning of the mode stirrer);
– continuous tuning (constant rotation of the stirrer);
– peak power acquisition on one revolution of the mode stirrer;
– averaged power calculation on one rotation of the mode stirrer.

When deciding on a measurement procedure, it shall be recognized that:

– discrete tuning is slow and requires a large number of sample measurements to be taken per revolution of the mode stirrer (200 is a usual value up to 20 GHz). This does, however, result in the acquisition of more accurate measurements;
– averaged power calculation during one revolution of the mode stirrer dramatically decreases the dynamic range of the method. In this case, acquisitions shall be recorded in watts (W) and not in dBm.

The measurement procedure described here is very economical in time, but requires a modern and stable spectrum analyser.

7.2 Measurement of the DUT

7.2.1 General

Depending on the available measurement instruments and the need on dynamic range, there are two possibilities on measurement.

7.2.2 Standard measurement

The standard measurement offers a high dynamic range, especially if power controlled amplifiers are used at the output of the generator.

The synthesized generator is connected to the input antenna and set to deliver a constant power at a fixed frequency. The mode stirrer is set to rotate at a constant speed (for example, 1 revolution every 5 s).

The spectrum analyser is connected to the output of the device under test. Its resolution filter is centred on the emitting frequency of the synthesizer and is fixed (SPAN 0: demodulator mode).

The spot scans the screen during a period which is equal to the time of one revolution of the mode stirrer.

The resulting trace which appears on the screen shows the evolution of the power as a function of the angular position of the mode stirrer.

After one complete revolution of the mode stirrer, the maximum value of the power is recorded.

Screening attenuation is then calculated, taking into account the attenuation of links and insertion loss of the cavity (equation (3)).

The same procedure is repeated for all the required test frequencies.

7.2.3 Fast measurement

For a faster measurement, a spectrum analyser with synchronized tracking generator is used [5]. The resolution bandwidth is set according to the requirements on dynamic range. Furthermore, the maximum hold function has to be used.

To calibrate the chamber set up and to determine the insertion loss, a first measurement is performed in which the spectrum analyser input is connected to the reference antenna and the tracking generator output is connected to the input antenna. The mode stirrer is turning continuously with e.g. 1 revolution every 5 s. The analyser needs to be set into a continuous sweep mode with max hold function. To ensure that a sufficient amount of independent samples have been recorded, the sweep time of the spectrum analyser and the revolution time of the stirred must not be equivalent or integer multiple of each other. If no changes in the max hold values can be recognized, the insertion loss of the chamber has been determined. Therefore, at least 20 sweeps are necessary.

For the determination of the screening attenuation, the tracking generator output has to be connected to the DUT instead of the input antenna and the measurement sequence from the first step is repeated. Then the screening attenuation simply can be calculated by subtracting the result from the first step from the one of the second step. This can either be done in a post processing step as well as by using the thru-calibration of modern spectrum analysers with build in tracking generators (therefore the first step is used to calibrate the system).

To check the maximum dynamic range, the DUT needs to be replaced by a shielded match load and the second measurement has to be performed with this configuration. If the result is not fulfilling the needs on dynamic range, the resolution bandwidth hast to be reduced. It has to be kept in mind that this might enlarge the measurement time a lot because a reduced measurement bandwidth is coming along with an enlarged sweep time.

7.3 Measurement of the insertion loss of the cavity

The synthesized generator is connected to the input antenna and set to deliver a constant power at a fixed frequency. The mode stirrer is also set to rotate at a constant speed. All parameters, i.e. rotation speed and spectrum analyzer set-up (except for input attenuator and reference level) shall be the same as those used during DUT measurement.

The spectrum analyser is connected to the output of the reference antenna. After a complete revolution of the mode stirrer, the maximum value of the power is recorded.

The insertion loss, Δ_{ins}, of the chamber is then calculated:

$$\Delta_{ins} = -10\log_{10}\left(\frac{P_{REF}}{P_{INJ}}\right) + X_L \quad (4)$$

where

P_{INJ} is the input power (W);

P_{REF} is the output power (W);

X_L is the insertion loss of linking devices (dB).

NOTE The insertion loss Δ_{ins} of the chamber is a function of frequency and is a characteristic of each reverberation chamber. It depends on construction parameters such as conductivity of panels, geometry, lossy materials inside the cavity, coupling through apertures, and measurement parameters such as rotation velocity of the mode stirrer and bandwidth of the spectrum filter. It may be measured either before each DUT measurement or made part of the test programme for an automated test system.

7.4 Control of the test set-up

7.4.1 Dynamic range

Prior to taking a set of measurements, the dynamic range of the test set-up shall be checked using the same linking devices (cables, connectors) and terminations as for the DUT, except that the DUT shall be replaced by a highly screened device. The dynamic range shall be at least 10 dB better than the specification of the DUT.

7.4.2 Insertion loss of the chamber

If the insertion loss of the chamber is part of the programme, in an automated test system, its suitability shall be checked before each set of measurements, a DUT being installed into the chamber. The spectrum analyzer shall be connected to the output of the reference antenna, which will be measured as if it was a DUT. If a preamplifier is used, it should not be overloaded; calibrated attenuators shall be added to the output of the reference antenna, as required, in order to prevent overload.

The screening attenuation should oscillate (±3 dB) around a 0 dB value, or around the value for the attenuators, if used. A systematic discrepancy indicates that the modelling of insertion loss is incorrect, either due to losses in the DUT (see 7.4.4) or to antenna problems.

7.4.3 Measurement of a calibrator

A calibrator is a device having stable screening attenuation. An example of a calibrator is given in Annex B. Such a calibrator should be measured during the full calibration procedure for the test set-up, and compared to previous measurements. This enables the detection of any deviations or malfunctioning of the test set-up.

The calibrator is the subject of on-going study to derive its theoretical screening attenuation from Z_t and Z_f, in order to provide the necessary data for calibration of the test equipment.

7.4.4 Measurement of lossy DUT

Some inaccuracy may occur when measuring a lossy DUT, due to insufficient moding of the reverberation chamber. This may be checked by verifying that during one revolution of the mode stirrer, the ratio between the maximum and the minimum power at the output of the reference antenna exceeds 20 dB.

7.5 Revolution speed of the mode stirrer

The speed of the mode stirrer has two effects on the test results:

– broadening of the frequency spectrum delivered by the synthesized generator;
– levelling of power peaks and gaps.

Due to both these effects, the same revolution speed and the same bandwidth of the analysis filter of the spectrum analyser should be used for both DUT and insertion loss measurements. If this is not done, a systematic error up to 10 dB could appear at higher frequencies.

In practice, one turn every 5 s is a good compromise between accuracy, measurement dynamic range and time saving.

7.6 Test frequencies

The mode stirred method exhibits significant changes in measured screening attenuation for close frequencies (±3 dB). This is due to real wave impedance at the maximum coupling position of the mode stirrer (the averaged wave impedance is 377 Ω, but the real wave impedance may vary widely [2]). To maintain accuracy, an adequate number of test frequencies should be taken. One hundred points per decade is an adequate value.

For narrow-band measurement, the screening attenuation value is the average of at least 10 closely spaced frequencies.

7.7 Voltage standing wave ratio (VSWR)

The individual components of the measurement system should be of good quality, with an input and output return loss of 15 dB or better. This applies especially to all components, cables and instrumentation in the signal paths between both the reference antenna and the DUT.

This requirement may be difficult to achieve for some DUTs, in which case a graph of return loss against frequency shall be included in the documentation. The return loss shall be ≥6 dB. Masking attenuators may also be used. Measurement shall be limited to the frequency range that can only be propagated by transverse electromagnetic modes (TEM).

8 Evaluation of the test results

By using the described test method, the screening attenuation of the DUT is measured. For the reasons given in 7.6, the ideal curve is not a smooth one. Whatever the frequency steps are, the measurements will oscillate around a mean curve. The order of magnitude of the oscillations is ±3 dB. The true screening attenuation under 377 Ω conditions is said to be the average curve. Care shall be taken not to confuse normal oscillations with resonances of the DUT.

These resonances may be distinguished by subdividing the frequency step, in which case normal oscillations will still present the same aspect whereas a resonance peak will be clearly apparent.

When loading the mode stirrer chamber with the DUT, the results shall be corrected by the corresponding power level difference measured with the receiving antenna.

Annex A
(informative)

Relationship between transfer impedance and screening attenuation

For a single hole leakage, the proposed relationship between the transfer impedance parameters and the screening attenuation is:

$$Z^2{}_t + Z^2{}_f = 2Z_1 \times Z_2 \times 10^{-a_s / 10} \tag{A.1}$$

where

Z_t is the surface transfer impedance (Ω);

Z_f is the capacitive coupling impedance (Ω);

Z_1 is the characteristic impedance of the internal system (usually 50 Ω);

Z_2 is equal to 377 Ω;

a_s is the screening attenuation.

For distributed leakages (ideal cables for example), this relation becomes:

$$Z^2{}_t + Z^2{}_f = \frac{2 \times Z_1 \times Z_2 \times 10^{-[a_s + S(D/\lambda)]/10}}{D^2} \tag{A.2}$$

where

$S(D/\lambda)$ is a summing function;

D is the length of the coupling zone;

λ is the free space wavelength (m).

($\lambda \equiv c/f$)

$$S(D/\lambda) = 10\log_{10} \frac{1}{\pi} \int_0^{\pi} \left[\frac{\sin\left[\frac{\pi D}{\lambda}\left(\cos\phi - \sqrt{\varepsilon}\right)\right]}{\left[\frac{\pi D}{\lambda}\left(\cos\phi - \sqrt{\varepsilon}\right)\right]} \right]^2 d\phi \tag{A.3}$$

where

ϕ is the angle coordinate in a cylindrical coordination system to be integrated from 0° to 180°.

ε is the relative permittivity of the cable.

Measurement experience shows that these formulae are accurate up to 5 GHz. For higher frequencies, they must be used with caution and the correct value for comparison should then be the screening attenuation.

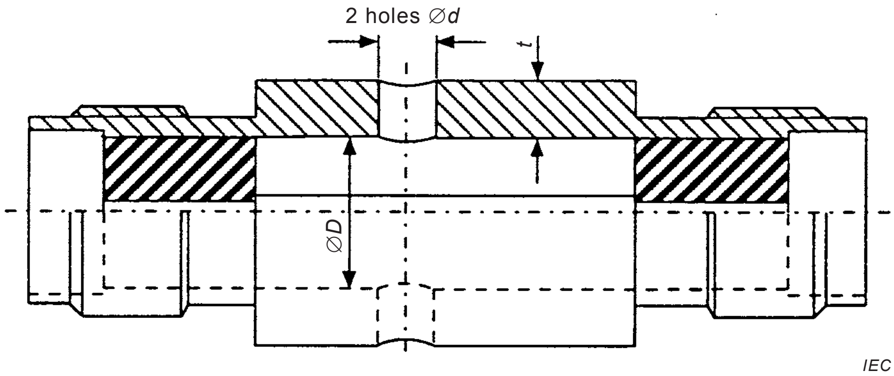
NOTE 1 This method does not allow Z_t and Z_f to be calculated separately. However, this is not usually a problem since Z_f is often equal to 0.

NOTE 2 For electrically long cables (more than 0,1λ at lowest test frequency), the screening attenuation can be assumed to be nearly constant versus frequency and length of the DUT when its surface transfer impedance increases by 20 dB/decade. This behaviour can be explained with the summing function, see IEC TS 62153-4-1.

Annex B
(informative)

Example of a calibrator

The centre part of the calibrator is a 50 Ω airline. End connectors are of a highly screened type such as SMA. Two holes diametrically opposed are drilled in the outer screen of the airline, see Figure B.1.



$D = 4{,}1 \times 10^{-3}$ m

$d = t = 2{,}15 \times 10^{-3}$ m

Figure B.1 – Basic construction details

As $d = t$, Z_f is negligible. Z_t can be computed using the following formulae (see [3] and [4]):

$$Z_t = 8d^3 [10^{-7} /(3D^2)] \times f \times e^{-3{,}68} \quad \text{(B.1)}$$

where f is the frequency (Hz).

Alternatively

$$Z_t = \frac{v\mu_0 d^3 \times f}{3\pi D^2} \times e^{\frac{-3{,}68t}{d}} \quad \text{(B.2)}$$

or

$$Z_t = \frac{4 \times 10^{-7} \times d^3 v}{3D^2} \times f \times e^{\frac{-3{,}68t}{d}} \quad \text{(B.3)}$$

where

v is the number of holes (in this application $v = 2$);

μ_0 is $4\pi \times 10^{-7}$ (Vs/Am);

f is the frequency in hertz (Hz).

The predicted screening attenuation in a reverberation chamber is (see Annex A)

$$a_s = -20\log_{10} \frac{Z_t}{\sqrt{2Z_1 \times Z_2}} \qquad \text{(B.4)}$$

if Z_1 = 50 Ω and Z_2 = 377 Ω

then $$a_s = \left[-\,20\log_{10} Z_t / (\Omega)\right] + 46\,(\text{dB}) \qquad \text{(B.5)}$$

With the values listed above, a_s at 1 GHz is typically +94 dB with the slope of –20 dB/decade.

The Z_t formula applies mainly for a triaxial or injection line test set-up having longitudinal currents on the calibrator.

Thus a perfect correlation between experimental measures and theoretical values cannot be expected. Nevertheless these formulae can be used to estimate the order of magnitude of the predicted screening attenuation.

Further studies are continuing in order to derive more accurate formulae for use during the reverberation chamber test set-up.

Bibliography

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