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INTERNATIONAL STANDARD

Metallic ~~communication~~ cables and other passive components – Test methods – Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance

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colour inside

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FOREWORD

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International Standard IEC 62153-4-8 has been prepared by 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 2006. This edition constitutes a technical revision.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

a) use of the triaxial set-up in a similar manner as for the measurement of the transfer impedance (see IEC 62153-4-3),
b) use of vector network analyser instead of capacitance bridge or pulse generator.

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

FDIS	Report on voting
46/684/FDIS	46/690/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 parts of the IEC 62153 series, under the general title: *Metallic cables and other passive components – Test methods*, 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- withdrawn,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.

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METALLIC COMMUNICATION CABLES AND OTHER PASSIVE COMPONENTS – TEST METHODS –

Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance

1 Scope

This part of IEC 62153 applies to metallic communications cables. It specifies a test method for determining the capacitive coupling admittance by the measurement of through capacitance using either a capacitance bridge or by a pulse method the capacitive coupling impedance and the coupling capacitance by the use of a triaxial set-up in a similar manner as for the measurement of the transfer impedance (see IEC 62153-4-3). Most cables have negligible capacitive coupling; however, in the case of cables with loose single-braids, the coupling through the holes in the screen shall be determined by the measurement of the capacitive coupling admittance.

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 60050-726, *International Electrotechnical Vocabulary (IEV) – Part 726: Transmission lines and wave guides*

IEC 61196-1, *Coaxial communication cables – Part 1: Generic specification – General, definitions and requirements*

IEC 62153-4-1, *Metallic communication cable test methods – Part 4-1: Electromagnetic Compatibility (EMC) – Introduction to electromagnetic (EMC) screening measurements*[1]

IEC 62153-4-3, *Metallic communication cable test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

3 Terms and definitions

For the purposes of this document the following terms and definitions given in IEC 60050-726, IEC 61196-1 and IEC 62153-4-1, as well as 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.

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[1] To be published.

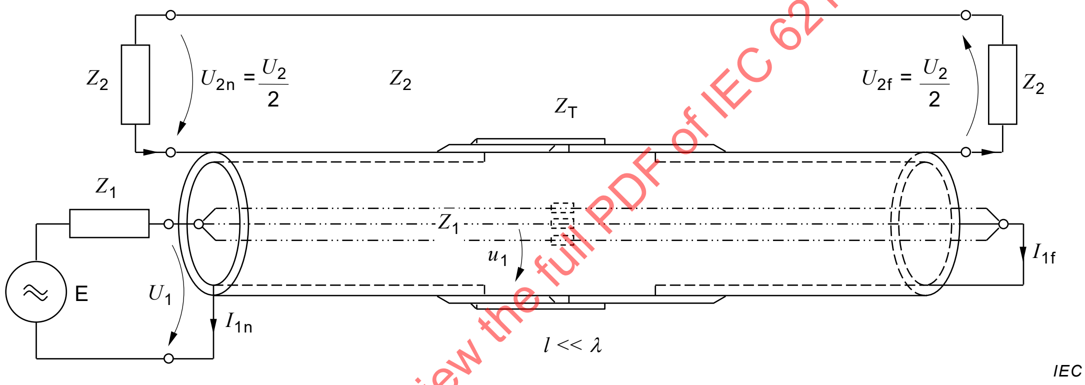
3.1
inner circuit
circuit consisting of the screens and the conductor(s) of the test specimen

Note 1 to entry: Quantities relating to the inner circuit are denoted by the subscript “1”. See Figure 1 and Figure 2.

3.2
outer circuit
circuit consisting of the screen surface and the inner surface of a surrounding test jig

Note 1 to entry: Quantities relating to the outer circuit are denoted by the subscript “2”. See Figure 1 and Figure 2.

3.3
transfer impedance
$\boldsymbol{Z_T}$
quotient of the longitudinal voltage induced in the matched outer circuit – formed by the screen under test and the measuring jig – and the current fed into the inner circuit or vice versa (see Figure 1)



Key

Z_1, Z_2	characteristic impedance of the inner and the outer circuits
U_1, U_2	voltages in the inner and the outer circuits (n: near end, f: far end)
I_1	current in the inner circuit (n: near end, f: far end)
l	length of the cable, respectively the length of the screen under test
λ	wavelength in free space

$$Z_T = \frac{U_2}{I_1} \qquad (1)$$

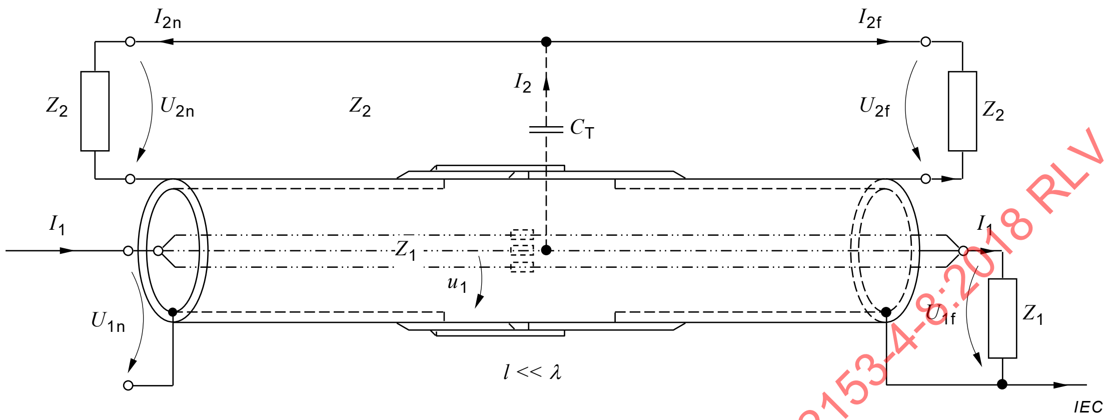
where

Z_T	is the transfer impedance;
U_2	is the voltage in the inner and the outer circuits (n: near end, f: far end);
I_1	is the current in the inner circuit (n: near end, f: far end).

Figure 1 – Definition of Z_T

Note 1 to entry: Transfer impedance is expressed in mΩ/m.

3.4
capacitive coupling impedance
Z_F
quotient of twice the voltage induced to the terminating impedance Z_2 of the matched outer circuit by a current I_1 fed (without returning over the screen) to the inner circuit and the current I_1 or vice versa (see Figure 2)



Key

Z_1, Z_2 characteristic impedance of the inner and the outer circuits

U_1, U_2 voltages in the inner and the outer circuits (n: near end, f: far end)

I_1, I_2 current in the inner and the outer circuits (n: near end, f: far end)

l length of the cable, respectively the length of the screen under test

λ wavelength in free space

$I_{2n} = I_{2f}$

$U_{1n} = U_{1f}$

$I_{2n} = I_{2f} = (1/2) \times I_2 = I_2/2$

$I_2 = I_{2n} + I_{2f}$

$$Z_F = \frac{U_{2n} + U_{2f}}{I_1} = \frac{2U_{2f}}{I_1} = Z_1 Z_2 \times j\omega C_T \quad (2)$$

where

Z_F is the capacitive coupling impedance;

Z_1, Z_2 is the characteristic impedance of the inner and the outer circuits;

U_2 is the voltage in the outer circuit (n: near end, f: far end);

I_1 is the current in the inner circuit (n: near end, f: far end);

C_T is the coupling capacitance.

Figure 2 – Definition of Z_F

Note 1 to entry: Capacitive coupling impedance is expressed in mΩ/m.

Note 2 to entry: For multiconductor cables, the inner conductors are shorted together.

Note 3 to entry: The coupling capacitance C_T is dependent on the dielectric permittivity and geometry of the outer circuit, whereas the capacitive coupling impedance is invariant with respect to the geometry of the outer circuit and nearly invariant with respect to the dielectric permittivity.

$$Z_F = Z_1 Z_2 j\omega C_T = j\omega C_T \frac{\sqrt{\varepsilon_{r1}}}{C_1 c_0} \frac{\sqrt{\varepsilon_{r2}}}{C_2 c_0} \tag{3}$$

where

Z_F is the capacitive coupling impedance;

C_T is the coupling capacitance;

ω is the circular frequency;

c_0 is the speed of light, 3×10^8 m/s;

ε_{r1} is the relative dielectric permittivity of the inner circuit (CUT);

ε_{r2} is the relative dielectric permittivity of the outer circuit (tube);

Z_1 is the impedance of the inner circuit (CUT);

Z_2 is the impedance of the outer circuit (tube);

C_1 is the capacitance of the inner circuit (CUT);

C_2 is the capacitance of the outer circuit (tube).

As $C_T \propto \frac{C_1 C_2}{\varepsilon_{r1} + \varepsilon_{r2}}$ one gets $Z_F \propto \frac{\sqrt{\varepsilon_{r1}\varepsilon_{r2}}}{\varepsilon_{r1} + \varepsilon_{r2}}$; and $\frac{\sqrt{\varepsilon_{r1}\varepsilon_{r2}}}{\varepsilon_{r1} + \varepsilon_{r2}} \approx 0{,}5$ for relative dielectric permittivity in the inner and outer circuit in the range from 1 to 3.

3.5
capacitive coupling admittance
Y_C
quotient of the current induced in the secondary (inner) circuit to the voltage development in the primary (outer) circuit. For electrically short uniform cables

$$Y_C = j\omega C_T \tag{4}$$

~~NOTE 1 Although most cables have negligible capacitive coupling, in the case of a loose single-braided cable, the coupling through the holes in the screen is described in terms of the through capacitance C_T or the capacitive coupling admittance Y_C.~~

~~NOTE 2 For multiconductor cables, the inner conductors are shorted together.~~

3.6
effective transfer impedance
Z_{TE}
maximum absolute value of the sum or difference of the Z_F and Z_T at every frequency

$$Z_{TE} = \max|Z_F \pm Z_T| \tag{5}$$

Note 1 to entry: The effective transfer impedance is expressed in Ω.

3.7
effective transfer impedance related to a reference impedance of 1 Ω
Z_{TE}
maximum absolute value of the sum or difference of the Z_F and Z_T at every frequency expressed in dB (Ω)

$$Z_{TE} = +20 \times \log_{10}\left(\frac{|Z_{TE}|}{Z_{T,ref}}\right) \tag{6}$$

where

$Z_{T,ref}$ is the reference transfer impedance with a value of 1 Ω

Note 1 to entry: The effective transfer impedance is expressed in dB (Ω).

3.8
coupling length
L_c
length of cable which is inside the test jig, i.e. the length of the screen under test

3.9
cut-off frequency
maximum frequency up to which the capacitive coupling admittance can be measured

~~**3.2**~~
~~**capacitive or capacitance transfer impedance**~~
~~the capacitive or capacitance transfer impedance is derived as:~~

$$Z_F = j\omega C_T Z_{01} Z_{02}$$

~~where~~

~~Z_{01} is the characteristic impedance of the primary circuit (outer braid or tube and screen of the test sample);~~

~~Z_{02} is the characteristic impedance of the secondary circuit (test sample).~~

~~NOTE For multiconductor cables, the inner conductors are shorted together.~~

~~4 Test equipment~~

~~4.1 General~~

~~The apparatus is of the “triple coaxial” form. The inner conductor(s) of the test sample is shielded at one end by means of a metal disc connected to the screen or by means of a screened termination without its resistor. The test sample is coaxially mounted inside a test jig. The outer conductor of the test jig is either a metal tube or is formed by applying a braid over the sheath of the test sample (or over a further insulating tube if the test sample has no sheath). The tube of braid is open-ended at the side opposite the metal disc.~~

~~4.2 Capacitance bridge method~~

~~The screen of the test sample is connected to the middle of a capacitance bridge, see Figure 1.~~

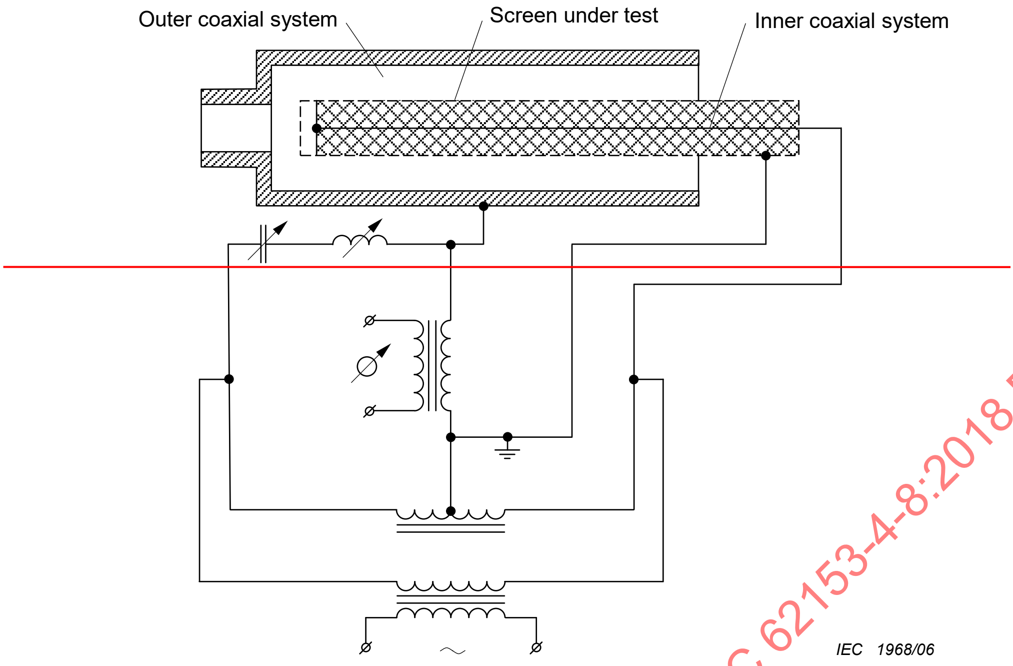


Figure 1 – Layout of the test circuit for the measurement of through capacitance by capacitance bridge method

4.3 Pulse method

The equipment combinations given in Table 1 are suggested to achieve a sensitivity of about 1 division on an oscilloscope screen for a value of C_T equal to 10^{-15} F/m, which is typically equivalent to a resolution of 1 mΩ/m in the derived value of Z_F.

Table 1 – Equipment combinations

Pulse generator		Oscilloscope	
Output pulse	Rise-time	Sensitivity	Bandwidth
10 V	100 ns	100 µV/div	1 MHz
100 V	100 ns	1 µV/div	1 MHz

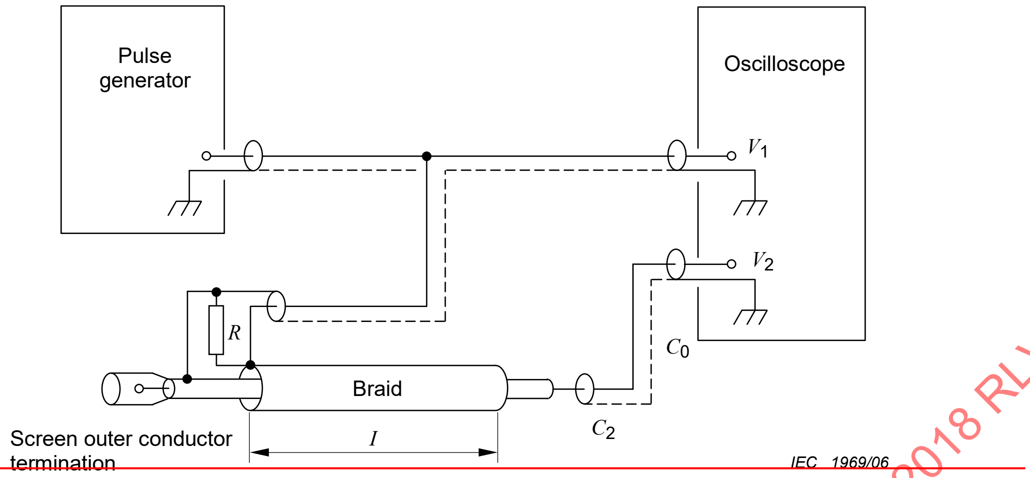
5 Procedure

5.1 Capacitance bridge method

At a frequency of approximately 1 kHz, the capacitance is measured between the inner conductor(s) of the test sample and the metal tube or outer braid.

5.2 Pulse method

The signal from a pulse generator is fed to the outer coaxial system (exciting circuit) and to one channel of the oscilloscope (V_1) (see Figure 2). The inner conductor(s) of the test sample is connected to the other channel of the oscilloscope (V_2). In order to avoid reflections from connector mismatch, V_2 is recorded as mean pulse height displayed 1 µs to 2 µs after the initiation of the pulse.



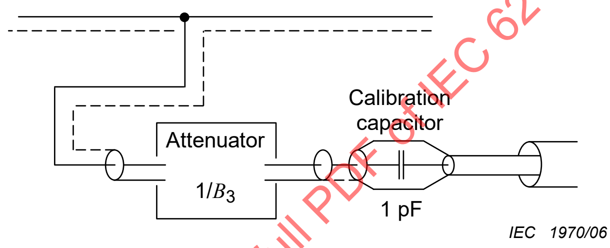


Figure 2 – Layout of test circuit for the measurement of through capacitance by pulse method

6 Measurement precautions

6.1 Capacitance bridge method

The screen under test shall have a length of between 0,5 m and 5 m to ensure that corrections for the connecting cable capacitance and measuring instrument capacitance do not unduly degrade the system accuracy.

6.2 Pulse method

The measuring circuit is not terminated in its characteristic impedance at either end so the overall length should be kept short to allow resonances to die away before the measurement is taken. The cable end is screened to avoid crosstalk from the pulse generator output. The exciting circuit is terminated to limit any resonances to the measuring circuit. The terminating resistance is placed at the drive end to avoid possible error from the surface transfer impedance contributions should any significant current flow in the screen under test.

To determine the sensitivity and calibrate the test equipment, an attenuator and a small calibration capacitor are used. To avoid introducing additional error, calibration can be effected at any level by substituting the calibration capacitor in place of the screened open circuit termination and connecting the pulse generator to it via the attenuator. In this way, the total measuring circuit capacitance is unchanged and the calibration level is C_3/B_3, the attenuator again being $1/B_3$.

If the pulse is correctly terminated before calibration there will be no change in the value of V_1, otherwise there will be a small change in V_1 as shown on the oscilloscope trace when the attenuator is substituted in place of the load resistor R_1.

Crosstalk sensitivity, which may limit the minimum detectable signal, is established by disconnecting at point P_3 and observing the V_2 oscilloscope trace with other settings normal. Care should be taken to screen the open end of the measuring cable, to maintain screen continuity by touching the connector bodies together and to set the pulse generator and the oscilloscope gain for the maximum desired sensitivity.

7 Expression of results

If the bridge method is used, the value of C_T in pF/m is the bridge reading divided by the length of the test sample.

If the pulse method is used the value of the through capacitance C_T is determined from:

$$C_T = (C_2 + C_0 / l) V_2 / V_1$$

where

C_2 is the capacitance of the inner dielectric of the test sample in pF/m;

l is the length of the test sample under the injection braid in m;

C_0 is the stray capacitance in pF/m;

V_1 is the reference pulse voltage;

V_2 is the coupled pulse voltage.

The stray capacitance consists of coupling capacitance, the oscilloscope input capacitance and the additional capacitance of the test sample outside the test length.

The capacitive coupling admittance Y_C in S/m is derived from:

$$Y_C = 2\pi f C_T / l$$

where

C_T is the through capacitance in pF/m;

l is the length of the test sample in m;

f is the frequency in Hz.

8 Determination of the capacitive or capacitance transfer impedance Z_F

The capacitive or capacitance transfer impedance can be readily derived from a measurement of the through capacitance of a braid if the characteristic impedance of the inner and outer coaxial lines are known. Both Z_{01} and Z_{02} can be obtained using the equipment assembled (see Figure 3) as a time domain reflectometer (TDR) so long as the pulse generator rise-time and the oscilloscope response are sufficiently fast.

NOTE For a 1 m test sample, the signal delay (go and return) is about 10 ns. A pulse generator with a rise-time of 4 ns and an oscilloscope with a bandwidth of 100 MHz gives a net rise-time of 5,5 ns which is sensibly shorter than the pulse length from the cable.

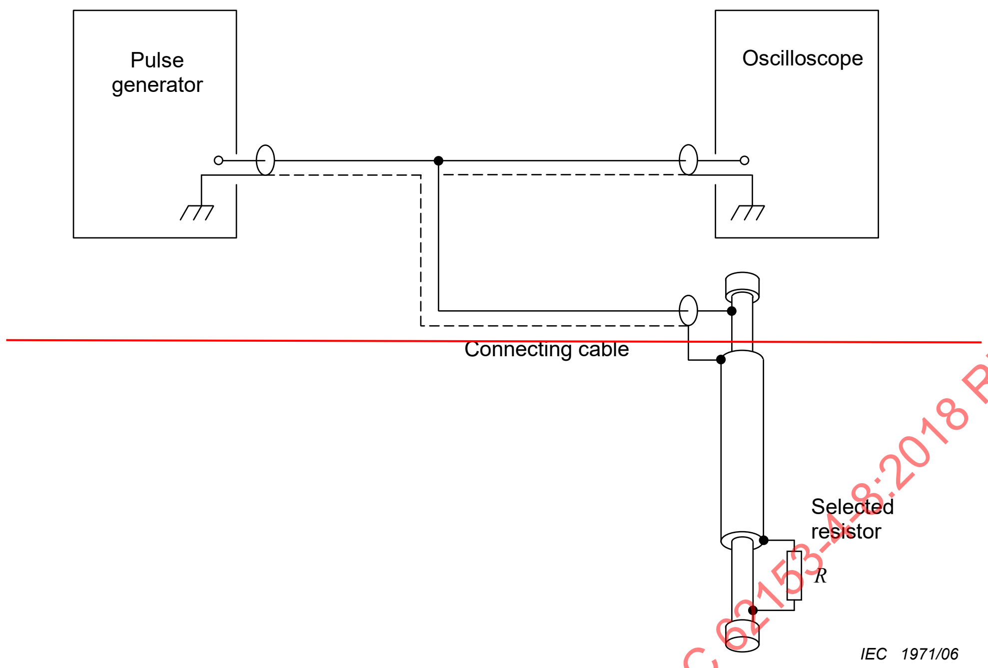


Figure 3 – Layout of test circuit for time domain measurement

The terminating resistor which is adjusted for minimum reflection becomes equivalent to the characteristic impedance of the circuit under test.

The capacitive or capacitance transfer impedance Z_F is derived from

$$Z_F = j\omega C_T Z_{01} Z_{02}$$

9 Requirement

The capacitive coupling admittance of the test sample shall comply with that indicated in the relevant cable specification.

4 Principle

The test determines the screening effectiveness of a shielded cable by applying a well-defined voltage to the screen of the cable and measuring the induced voltage in a secondary circuit in order to determine the capacitive coupling admittance. This test measures only the electrostatic component of the effective transfer impedance Z_{TE}. To measure the magnetic component (the surface transfer impedance), the method described in IEC 62153-4-3 shall be used.

5 Test method

5.1 General

If not otherwise specified, the measurements shall be carried out at the temperature of (23 ± 3) °C.

The test method determines the capacitive coupling admittance of a cable screen by measuring the cable in a triaxial test set-up. A test configuration with an open circuit in the inner and outer circuit shall be used. This emphasizes the capacitive coupling compared to the magnetic coupling and results in a 6 dB higher signal compared to a configuration where the inner circuit is matched.

The test results are valid in a frequency range up to about 25 MHz, see 5.2. The coupling capacitance C_T is independent on the frequency. Therefore for frequencies above the cut-off frequency, the test results of the capacitive coupling admittance can be extrapolated with 20 dB/decade, see 3.5.

5.2 Cut-off frequency

The cut-off frequency length product is roughly:

$$f_{cut} \times l \approx \frac{1}{\sqrt{\varepsilon_{r1} + \varepsilon_{r2}}} \frac{c_0}{2\pi} \tag{7}$$

where

l is the coupling length of the cable under test;

c_0 is the speed of light, 3×10^8m/s;

ε_{r1} is the relative dielectric permittivity of the inner circuit (CUT);

ε_{r2} is the relative dielectric permittivity of the outer circuit (tube).

I.e. for a coupling length of 1 m and dielectric permittivities of 2,3 and 1,1 in the inner respectively outer circuit, the maximum frequency for the measurement of the capacitive coupling admittance is 25 MHz.

Another way to obtain the cut-off frequency is to observe the phase of the capacitive coupling admittance respectively measured forward transmission scattering parameter S_{21}, see 5.8. The cut-off frequency is reached when the phase starts to deviate from 90 degrees.

5.3 Test equipment

The measurement shall be performed using a vector network analyser.

5.4 Coupling length

The coupling length shall be not shorter than 0,5 m and not longer than 1,0 m.

5.5 Sample preparation

The test sample shall have a length not more than 50 % longer than the coupling length.

Coaxial cables are prepared as shown in Figure 3.

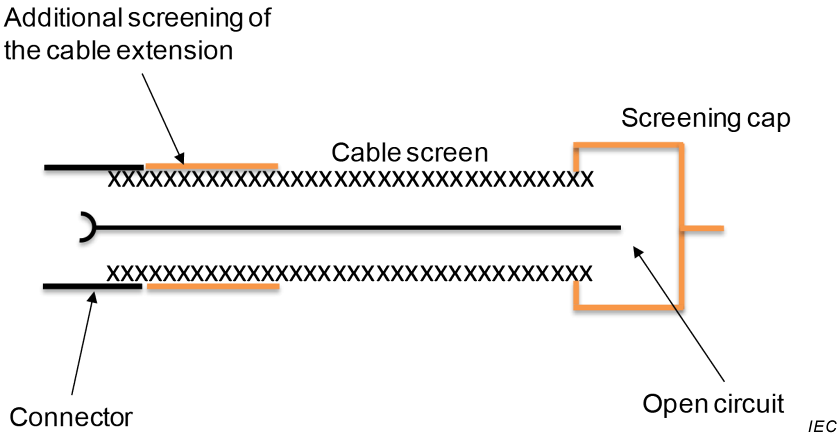


Figure 3 – Preparation of test sample for coaxial cables

One end of the coaxial cable is prepared with a connector to make a connection to the receiver. The other end of the coaxial cable is prepared with a well screened open circuit. The open circuit shall be made in a way resulting in a small stray capacitance. To minimize unwanted coupling into the tube, the exceeding length outside the tube shall be screened with an additional tight screen, which shall be in contact with the cable screen (e.g. by wrapping a metal foil with minimum 20 % overlap around the cable screen).

All connections shall be made RF tight and with low RF-contact resistance so that the impact of the sample preparation is negligible compared to the test results.

Screened symmetrical cables are treated as a quasi coaxial system, see Figure 4. Therefore the conductors of all pairs/quads shall be connected together at both ends. All screens, including those of individually screened pairs/quads, shall be connected together at both ends. The screens shall be connected over the whole circumference.

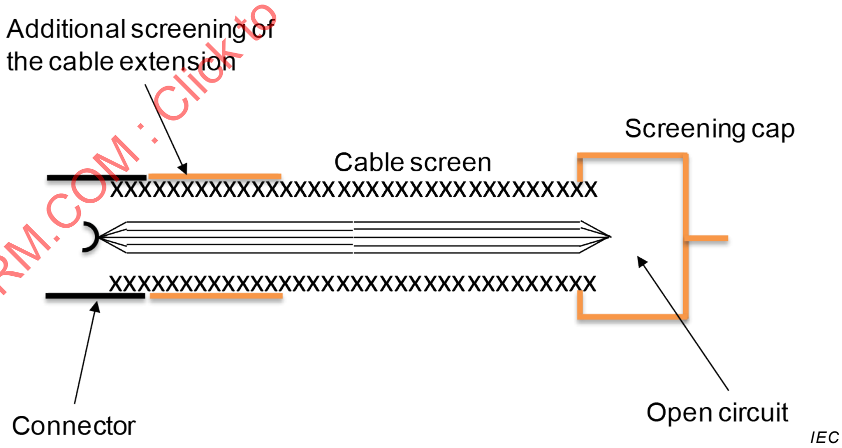


Figure 4 – Preparation of test sample for symmetrical cables

5.6 Test set-up

The test sample shall be fitted to the test set-up. The test set-up is an apparatus of a triple coaxial form. The cable screen forms both the outer conductor of the inner circuit and the inner conductor of the outer circuit. The outer conductor of the outer circuit is a well conductive tube of non-ferromagnetic metal (for example brass, copper or aluminium) with an open-circuit to the screen on the receiver side of the cable (see Figure 5). The test sample shall be well centered in the tube.

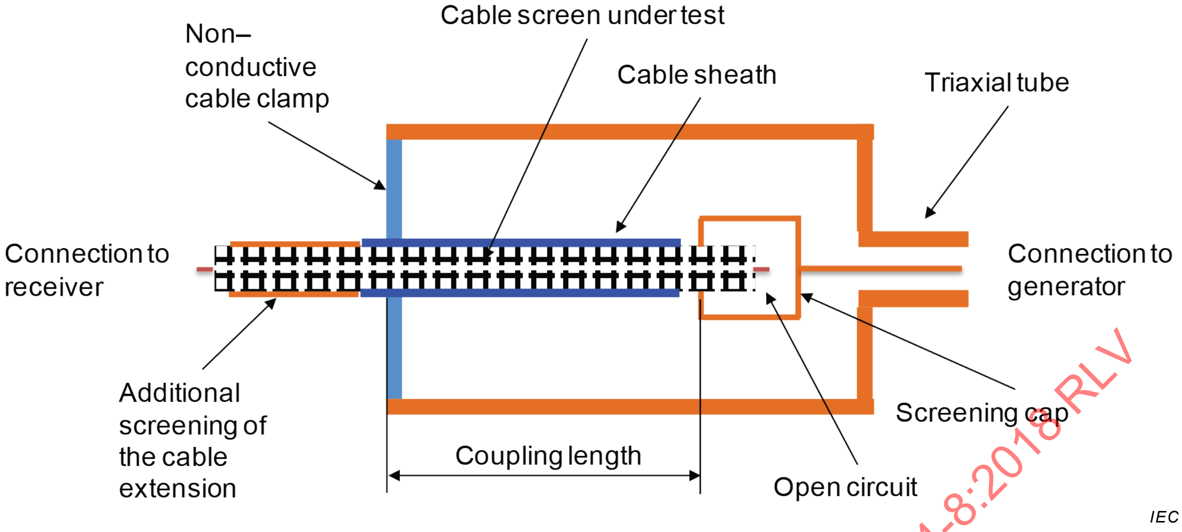


Figure 5 – Triaxial set-up

Due to the open circuit in the outer circuit (tube), external disturbers may couple into the tube. Therefore the generator signal is feeding the outer circuit (tube), guaranteeing a high signal to noise ratio. The coupled signal is measured in the inner circuit (cable), see Figure 6. The connection from the triaxial set-up to the vector network analyzer (VNA) shall be done with well screened cables, e.g. double braided cables, having a screening attenuation of minimum 80 dB up to 1 GHz and a transfer impedance of maximum 10 mΩ/m at 100 MHz. The connecting cables shall be as short as possible. The use of ferrites on the connecting cables is recommended in order to suppress resonance effects.

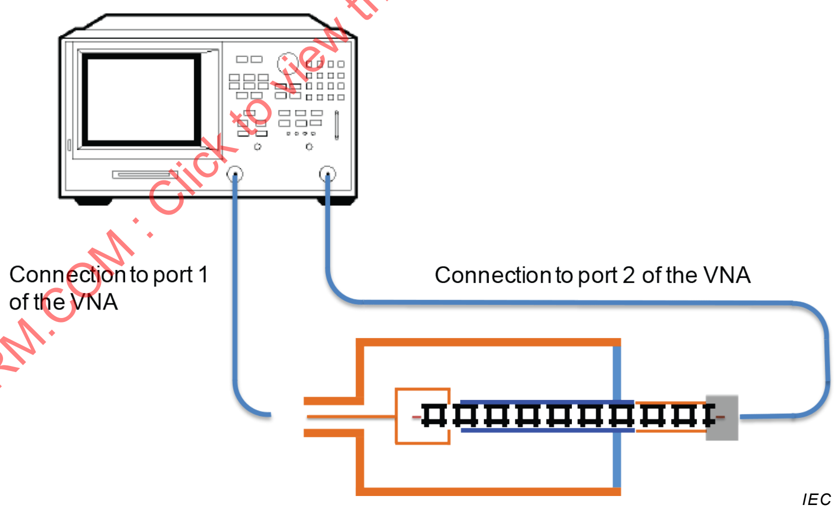


Figure 6 – Connection to the vector network analyzer

5.7 Calibration procedure

The calibration shall be established at the same frequency points at which the measurement of the transfer impedance is done, i.e. in a logarithmic frequency sweep over the whole frequency range, which is specified for the capacitive coupling admittance.

A full two-port calibration – including isolation – shall be established including the connecting cables used to connect the test set-up to the test equipment. The reference planes for the calibration are the connector interface of the connecting cables. Further details on how to perform a full two port calibration are found in the manual of the vector network analyzer.

5.8 Measuring procedure

The outer circuit (tube) of the triaxial set-up shall be connected to port 1 of the VNA. The inner circuit (sample) shall be connected to port 2 of the VNA, see Figure 6. The connection to the VNA shall be done with the same cables as used during the calibration, see 5.6 and 5.7.

The forward transmission scattering parameter S_{21} shall be measured in a logarithmic frequency sweep over the whole frequency range, which is specified for the capacitive coupling admittance and at the same frequency points as for the calibration procedure:

$$a_{\text{meas}} = 20\log_{10}\left(\frac{\sqrt{P_1}}{\sqrt{P_2}}\right) = -20\log_{10}\left(S_{21}\right) \tag{8}$$

where

P_1 is the fictive unreflected power fed to outer circuit;

P_2 is the power in the inner circuit.

5.9 Evaluation of test results

5.9.1 General

The conversion from the measured attenuation to the capacitive coupling admittance is given by the following formulae:

$$|Y_{\text{C}}| = \frac{1}{Z_0 \cdot L_{\text{c}}} 10^{-\frac{a_{\text{meas}}}{20}} \tag{9}$$

$$Z_{\text{F}} = Z_1 Z_2 Y_{\text{T}} \tag{10}$$

$$C_{\text{T}} = \frac{|Y_{\text{T}}|}{\omega} \tag{11}$$

where

Y_{C} is the capacitive coupling admittance;

Z_{F} is the capacitive coupling impedance;

Z_1 is the impedance of the inner circuit;

Z_2 is the impedance of the outer circuit;

C_{T} is the coupling capacitance;

Z_0 is the system impedance (in general 50 Ω);

L_{c} is the coupling length;

a_{meas} is the attenuation measured at the measuring procedure;

ω is the circular frequency.

5.9.2 Test report

~~The test report shall give the test conditions:~~

- ~~the used method (pulse or bridge);~~
- ~~the length of the test sample;~~
- ~~the frequency used to determine the capacitive coupling admittance,~~

~~and record the result of the measurement according to Clause 7 and Clause 8 of this part of IEC 62153.~~

The test report shall conclude if the requirements of the relevant cable specification are met and include:

a) graph with logarithmic frequency scale of the magnitude (in dB) of the measured forward transmission scattering parameter S_{21};

a) graph with logarithmic frequency scale of the phase (in degree) of the measured forward transmission scattering parameter S_{21};

b) graph with double logarithmic scale of the derived capacitive coupling admittance Y_T;

c) graph with double logarithmic scale of the derived capacitive coupling impedance Z_F;

d) graph with double logarithmic scale of the derived coupling capacitance C_T;

e) value of the impedance and capacitance of the inner and outer circuit;

f) value of the coupling length.

Bibliography

Optimierte Kabelschirme – Theorie und Messung; DISS. ETH Nr. 9354; Thomas Kley

IEC 62153-4-8

Edition 2.0 2018-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Metallic cables and other passive components – Test methods – Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance

Câbles métalliques et autres composants passifs – Méthodes d'essai – Partie 4-8: Compatibilité électromagnétique (CEM) – Admittance de couplage capacitif

IEC 62153-4-8:2018-06(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

METALLIC CABLES AND OTHER PASSIVE COMPONENTS – TEST METHODS –

Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance

FOREWORD

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International Standard IEC 62153-4-8 has been prepared by 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 2006. This edition constitutes a technical revision.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

a) use of the triaxial set-up in a similar manner as for the measurement of the transfer impedance (see IEC 62153-4-3),

b) use of vector network analyser instead of capacitance bridge or pulse generator.

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

FDIS	Report on voting
46/684/FDIS	46/690/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 parts of the IEC 62153 series, under the general title: *Metallic cables and other passive components – Test methods*, 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

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- withdrawn,
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METALLIC CABLES AND OTHER PASSIVE COMPONENTS – TEST METHODS –

Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance

1 Scope

This part of IEC 62153 specifies a test method for determining the capacitive coupling admittance, the capacitive coupling impedance and the coupling capacitance by the use of a triaxial set-up in a similar manner as for the measurement of the transfer impedance (see IEC 62153-4-3). Most cables have negligible capacitive coupling; however, in the case of cables with loose single-braids, the coupling through the holes in the screen shall be determined by the measurement of the capacitive coupling admittance.

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 62153-4-3, *Metallic communication cable test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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.

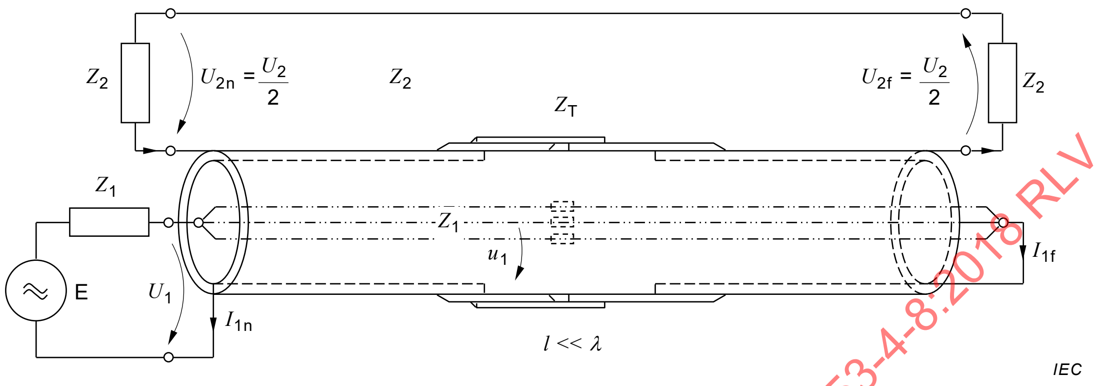
3.1
inner circuit
circuit consisting of the screens and the conductor(s) of the test specimen

Note 1 to entry: Quantities relating to the inner circuit are denoted by the subscript "1". See Figure 1 and Figure 2.

3.2
outer circuit
circuit consisting of the screen surface and the inner surface of a surrounding test jig

Note 1 to entry: Quantities relating to the outer circuit are denoted by the subscript "2". See Figure 1 and Figure 2.

3.3
transfer impedance
$\boldsymbol{Z_T}$
quotient of the longitudinal voltage induced in the matched outer circuit – formed by the screen under test and the measuring jig – and the current fed into the inner circuit or vice versa (see Figure 1)



Key

Z_1, Z_2	characteristic impedance of the inner and the outer circuits
U_1, U_2	voltages in the inner and the outer circuits (n: near end, f: far end)
I_1	current in the inner circuit (n: near end, f: far end)
l	length of the cable, respectively the length of the screen under test
λ	wavelength in free space

$$Z_T = \frac{U_2}{I_1} \tag{1}$$

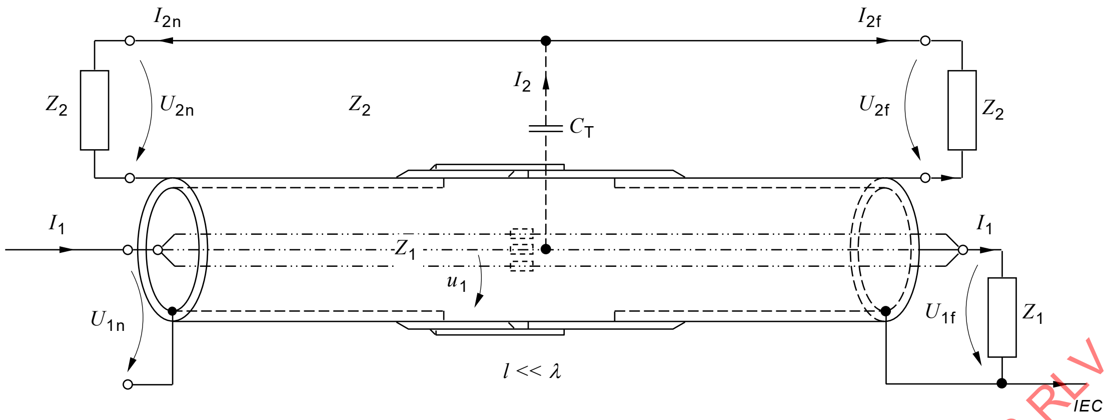
where

Z_T is the transfer impedance;
U_2 is the voltage in the inner and the outer circuits (n: near end, f: far end);
I_1 is the current in the inner circuit (n: near end, f: far end).

Figure 1 – Definition of Z_T

Note 1 to entry: Transfer impedance is expressed in mΩ/m.

3.4
capacitive coupling impedance
$\boldsymbol{Z_F}$
quotient of twice the voltage induced to the terminating impedance Z_2 of the matched outer circuit by a current I_1 fed (without returning over the screen) to the inner circuit and the current I_1 or vice versa (see Figure 2)



Key

Z_1, Z_2 characteristic impedance of the inner and the outer circuits

U_1, U_2 voltages in the inner and the outer circuits (n: near end, f: far end)

I_1, I_2 current in the inner and the outer circuits (n: near end, f: far end)

l length of the cable, respectively the length of the screen under test

λ wavelength in free space

$I_{2n} = I_{2f}$

$U_{1n} = U_{1f}$

$I_{2n} = I_{2f} = (1/2) \times I_2 = I_2/2$

$I_2 = I_{2n} + I_{2f}$

$$Z_F = \frac{U_{2n} + U_{2f}}{I_1} = \frac{2U_{2f}}{I_1} = Z_1 Z_2 \times j\omega C_T \qquad (2)$$

where

Z_F is the capacitive coupling impedance;

Z_1, Z_2 is the characteristic impedance of the inner and the outer circuits;

U_2 is the voltage in the outer circuit (n: near end, f: far end);

I_1 is the current in the inner circuit (n: near end, f: far end);

C_T is the coupling capacitance.

Figure 2 – Definition of Z_F

Note 1 to entry: Capacitive coupling impedance is expressed in mΩ/m.

Note 2 to entry: For multiconductor cables, the inner conductors are shorted together.

Note 3 to entry: The coupling capacitance C_T is dependent on the dielectric permittivity and geometry of the outer circuit, whereas the capacitive coupling impedance is invariant with respect to the geometry of the outer circuit and nearly invariant with respect to the dielectric permittivity.

$$Z_F = Z_1 Z_2 j\omega C_T = j\omega C_T \frac{\sqrt{\varepsilon_{r1}}}{C_1 c_0} \frac{\sqrt{\varepsilon_{r2}}}{C_2 c_0} \qquad (3)$$

where

Z_F is the capacitive coupling impedance;

C_T is the coupling capacitance;

ω is the circular frequency;

c_0 is the speed of light, 3 × 10^8m/s;
ε_{r1} is the relative dielectric permittivity of the inner circuit (CUT);
ε_{r2} is the relative dielectric permittivity of the outer circuit (tube);
Z_1 is the impedance of the inner circuit (CUT);
Z_2 is the impedance of the outer circuit (tube);
C_1 is the capacitance of the inner circuit (CUT);
C_2 is the capacitance of the outer circuit (tube).

As $C_T \propto \frac{C_1 C_2}{\varepsilon_{r1}+\varepsilon_{r2}}$ one gets $Z_F \propto \frac{\sqrt{\varepsilon_{r1}\varepsilon_{r2}}}{\varepsilon_{r1}+\varepsilon_{r2}}$; and $\frac{\sqrt{\varepsilon_{r1}\varepsilon_{r2}}}{\varepsilon_{r1}+\varepsilon_{r2}} \approx 0{,}5$ for relative dielectric permittivity in the inner and outer circuit in the range from 1 to 3.

3.5
capacitive coupling admittance
Y_C
quotient of the current induced in the secondary (inner) circuit to the voltage development in the primary (outer) circuit. For electrically short uniform cables

$$Y_C = j\omega C_T \tag{4}$$

3.6
effective transfer impedance
Z_{TE}
maximum absolute value of the sum or difference of the Z_F and Z_T at every frequency

$$Z_{TE} = \max|Z_F \pm Z_T| \tag{5}$$

Note 1 to entry: The effective transfer impedance is expressed in Ω.

3.7
effective transfer impedance related to a reference impedance of 1 Ω
Z_{TE}
maximum absolute value of the sum or difference of the Z_F and Z_T at every frequency expressed in dB (Ω)

$$Z_{TE} = +20 \times \log_{10}\left(\frac{|Z_{TE}|}{Z_{T,ref}}\right) \tag{6}$$

where

$Z_{T,ref}$ is the reference transfer impedance with a value of 1 Ω

Note 1 to entry: The effective transfer impedance is expressed in dB (Ω).

3.8
coupling length
L_c
length of cable which is inside the test jig, i.e. the length of the screen under test

3.9
cut-off frequency
maximum frequency up to which the capacitive coupling admittance can be measured

4 Principle

The test determines the screening effectiveness of a shielded cable by applying a well-defined voltage to the screen of the cable and measuring the induced voltage in a secondary circuit in order to determine the capacitive coupling admittance. This test measures only the electrostatic component of the effective transfer impedance Z_{TE}. To measure the magnetic component (the surface transfer impedance), the method described in IEC 62153-4-3 shall be used.

5 Test method

5.1 General

If not otherwise specified, the measurements shall be carried out at the temperature of (23 ± 3) °C.

The test method determines the capacitive coupling admittance of a cable screen by measuring the cable in a triaxial test set-up. A test configuration with an open circuit in the inner and outer circuit shall be used. This emphasizes the capacitive coupling compared to the magnetic coupling and results in a 6 dB higher signal compared to a configuration where the inner circuit is matched.

The test results are valid in a frequency range up to about 25 MHz, see 5.2. The coupling capacitance C_T is independent on the frequency. Therefore for frequencies above the cut-off frequency, the test results of the capacitive coupling admittance can be extrapolated with 20 dB/decade, see 3.5.

5.2 Cut-off frequency

The cut-off frequency length product is roughly:

$$f_{\text{cut}} \times l \approx \frac{1}{\sqrt{\varepsilon_{r1} + \varepsilon_{r2}}} \frac{c_0}{2\pi} \tag{7}$$

where

l is the coupling length of the cable under test;

c_0 is the speed of light, 3×10^8 m/s;

ε_{r1} is the relative dielectric permittivity of the inner circuit (CUT);

ε_{r2} is the relative dielectric permittivity of the outer circuit (tube).

I.e. for a coupling length of 1 m and dielectric permittivities of 2,3 and 1,1 in the inner respectively outer circuit, the maximum frequency for the measurement of the capacitive coupling admittance is 25 MHz.

Another way to obtain the cut-off frequency is to observe the phase of the capacitive coupling admittance respectively measured forward transmission scattering parameter S_{21}, see 5.8. The cut-off frequency is reached when the phase starts to deviate from 90 degrees.

5.3 Test equipment

The measurement shall be performed using a vector network analyser.

5.4 Coupling length

The coupling length shall be not shorter than 0,5 m and not longer than 1,0 m.

5.5 Sample preparation

The test sample shall have a length not more than 50 % longer than the coupling length.

Coaxial cables are prepared as shown in Figure 3.

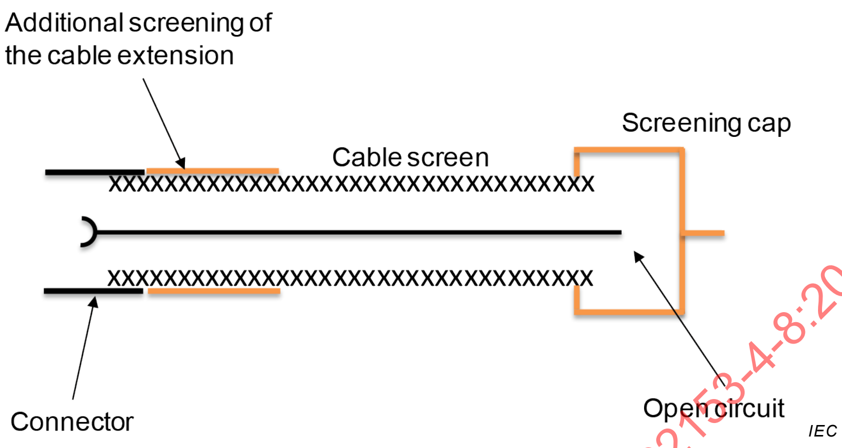


Figure 3 – Preparation of test sample for coaxial cables

One end of the coaxial cable is prepared with a connector to make a connection to the receiver. The other end of the coaxial cable is prepared with a well screened open circuit. The open circuit shall be made in a way resulting in a small stray capacitance. To minimize unwanted coupling into the tube, the exceeding length outside the tube shall be screened with an additional tight screen, which shall be in contact with the cable screen (e.g. by wrapping a metal foil with minimum 20 % overlap around the cable screen).

All connections shall be made RF tight and with low RF-contact resistance so that the impact of the sample preparation is negligible compared to the test results.

Screened symmetrical cables are treated as a quasi coaxial system, see Figure 4. Therefore the conductors of all pairs/quads shall be connected together at both ends. All screens, including those of individually screened pairs/quads, shall be connected together at both ends. The screens shall be connected over the whole circumference.

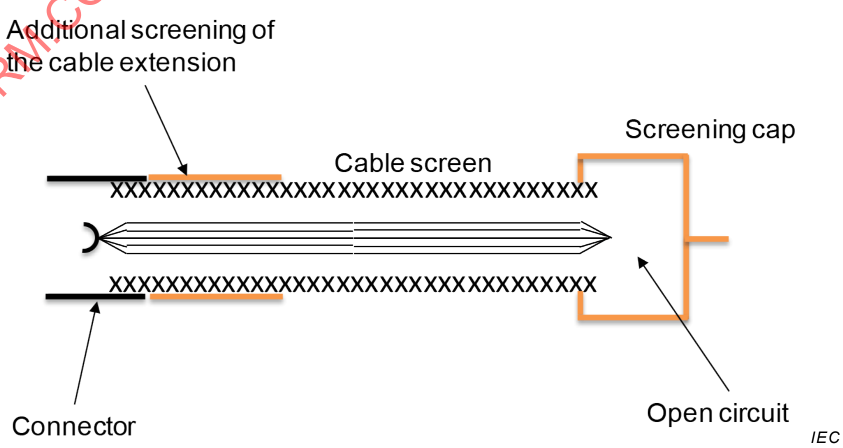


Figure 4 – Preparation of test sample for symmetrical cables

5.6 Test set-up

The test sample shall be fitted to the test set-up. The test set-up is an apparatus of a triple coaxial form. The cable screen forms both the outer conductor of the inner circuit and the inner conductor of the outer circuit. The outer conductor of the outer circuit is a well conductive tube of non-ferromagnetic metal (for example brass, copper or aluminium) with an open-circuit to the screen on the receiver side of the cable (see Figure 5). The test sample shall be well centered in the tube.

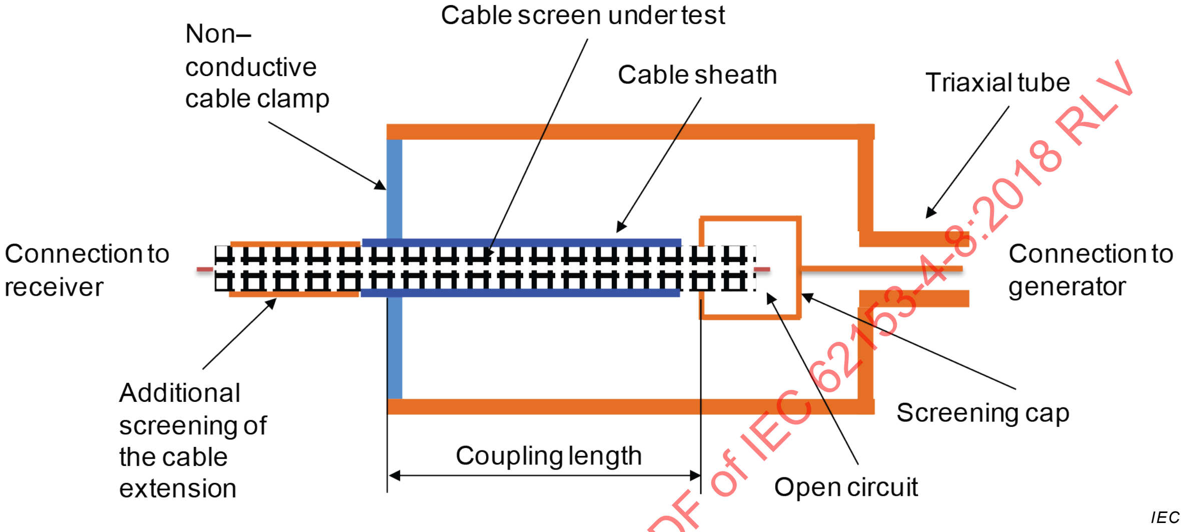


Figure 5 – Triaxial set-up

Due to the open circuit in the outer circuit (tube), external disturbers may couple into the tube. Therefore the generator signal is feeding the outer circuit (tube), guaranteeing a high signal to noise ratio. The coupled signal is measured in the inner circuit (cable), see Figure 6. The connection from the triaxial set-up to the vector network analyzer (VNA) shall be done with well screened cables, e.g. double braided cables, having a screening attenuation of minimum 80 dB up to 1 GHz and a transfer impedance of maximum 10 mΩ/m at 100 MHz. The connecting cables shall be as short as possible. The use of ferrites on the connecting cables is recommended in order to suppress resonance effects.

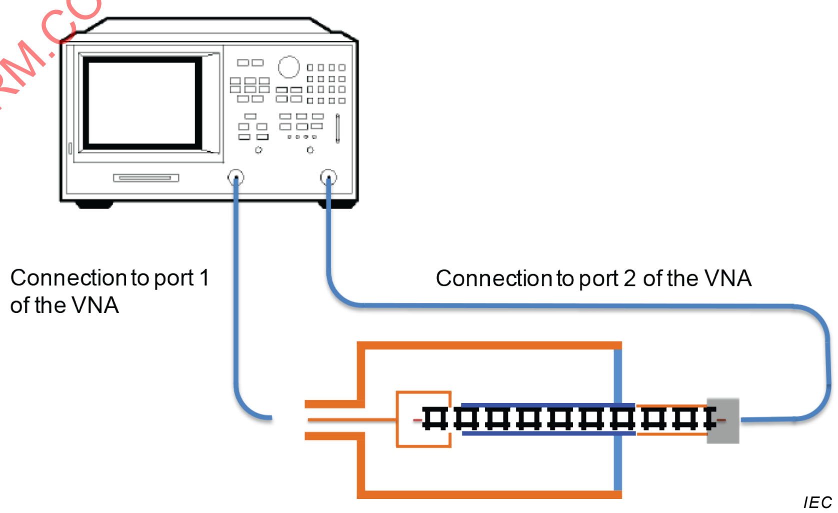


Figure 6 – Connection to the vector network analyzer

5.7 Calibration procedure

The calibration shall be established at the same frequency points at which the measurement of the transfer impedance is done, i.e. in a logarithmic frequency sweep over the whole frequency range, which is specified for the capacitive coupling admittance.

A full two-port calibration – including isolation – shall be established including the connecting cables used to connect the test set-up to the test equipment. The reference planes for the calibration are the connector interface of the connecting cables. Further details on how to perform a full two port calibration are found in the manual of the vector network analyzer.

5.8 Measuring procedure

The outer circuit (tube) of the triaxial set-up shall be connected to port 1 of the VNA. The inner circuit (sample) shall be connected to port 2 of the VNA, see Figure 6. The connection to the VNA shall be done with the same cables as used during the calibration, see 5.6 and 5.7.

The forward transmission scattering parameter S_{21} shall be measured in a logarithmic frequency sweep over the whole frequency range, which is specified for the capacitive coupling admittance and at the same frequency points as for the calibration procedure:

$$a_{\text{meas}} = 20\log_{10}\left(\frac{\sqrt{P_1}}{\sqrt{P_2}}\right) = -20\log_{10}\left(\text{S}_{21}\right) \qquad (8)$$

where

P_1 is the fictive unreflected power fed to outer circuit;

P_2 is the power in the inner circuit.

5.9 Evaluation of test results

5.9.1 General

The conversion from the measured attenuation to the capacitive coupling admittance is given by the following formulae:

$$\left|Y_\text{C}\right| = \frac{1}{Z_0 \cdot L_\text{c}} 10^{-\frac{a_{\text{meas}}}{20}} \qquad (9)$$

$$Z_\text{F} = Z_1 Z_2 Y_\text{T} \qquad (10)$$

$$C_\text{T} = \frac{\left|Y_\text{T}\right|}{\omega} \qquad (11)$$

where

Y_C is the capacitive coupling admittance;

Z_F is the capacitive coupling impedance;

Z_1 is the impedance of the inner circuit;

Z_2 is the impedance of the outer circuit;

C_T is the coupling capacitance;

Z_0 is the system impedance (in general 50 Ω);

L_c is the coupling length;

a_{meas} is the attenuation measured at the measuring procedure;

ω is the circular frequency.

5.9.2 Test report

The test report shall conclude if the requirements of the relevant cable specification are met and include:

a) graph with logarithmic frequency scale of the magnitude (in dB) of the measured forward transmission scattering parameter S_{21};
b) graph with logarithmic frequency scale of the phase (in degree) of the measured forward transmission scattering parameter S_{21};
c) graph with double logarithmic scale of the derived capacitive coupling admittance Y_T;
d) graph with double logarithmic scale of the derived capacitive coupling impedance Z_F;
e) graph with double logarithmic scale of the derived coupling capacitance C_T;
f) value of the impedance and capacitance of the inner and outer circuit;
g) value of the coupling length.

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SOMMAIRE

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CÂBLES MÉTALLIQUES ET AUTRES COMPOSANTS PASSIFS – MÉTHODES D'ESSAI –

Partie 4-8: Compatibilité électromagnétique (CEM) – Admittance de couplage capacitif

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La Norme internationale IEC 62153-4-8 a été établie par le comité d'études 46 de l'IEC: Câbles, fils, guides d'ondes, connecteurs, composants passifs pour micro-onde et accessoires.

Cette deuxième édition annule et remplace la première édition parue en 2006. Cette édition constitue une révision technique.

Les futures normes de cette série porteront dorénavant le nouveau titre général cité ci-dessus. Le titre des normes existant déjà dans cette série sera mis à jour lors de la prochaine édition.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) l'utilisation d'un montage triaxial similaire à celui utilisé pour le mesurage de l'impédance de transfert (voir l'IEC 62153-4-3),
b) l'utilisation d'un analyseur de réseau vectoriel en lieu et place d'un pont capacitif ou d'un générateur d'impulsions.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
46/684/FDIS	46/690/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 62153, publiées sous le titre général: *Câbles métalliques et autres composants passifs – Méthodes d'essai*, peut être consultée sur le site web de l'IEC.

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CÂBLES MÉTALLIQUES ET AUTRES COMPOSANTS PASSIFS – MÉTHODES D'ESSAI –

Partie 4-8: Compatibilité électromagnétique (CEM) – Admittance de couplage capacitif

1 Domaine d'application

La présente partie de l'IEC 62153 spécifie une méthode d'essai pour la détermination de l'admittance de couplage capacitif, l'impédance de couplage capacitif et la capacité de couplage par l'utilisation d'un montage triaxial similaire à celui utilisé pour le mesurage de l'impédance de transfert (voir l'IEC 62153-4-3). La plupart des câbles présentent un couplage capacitif négligeable. Cependant, dans le cas d'un câble à tressage individuel détendu, le couplage à travers les trous de l'écran doit être déterminé par le mesurage de l'admittance de couplage capacitif.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 62153-4-3, *Metallic communication cable test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
circuit interne
circuit composé des écrans et du ou des conducteurs de l'éprouvette

Note 1 à l'article: Les grandeurs relatives au circuit interne sont indiquées par l'indice «1». Voir la Figure 1 et la Figure 2.

3.2
circuit externe
circuit composé de la surface de l'écran et de la surface interne d'un montage d'essai enveloppant

Note 1 à l'article: Les grandeurs relatives au circuit externe sont indiquées par l'indice «2». Voir la Figure 1 et la Figure 2.