INTERNATIONAL STANDARD

IEC 62153-4-4

First edition
2006-05

Metallic communication cable test methods –

Part 4-4:
Electromagnetic compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation a_S up to and above 3 GHz

Reference number
IEC 62153-4-4:2006(E)

Publication numbering

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Commission Electrotechnique Internationale
International Electrotechnical Commission
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PRICE CODE P

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-4: Electromagnetic compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation a_s up to and above 3 GHz

FOREWORD

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International Standard IEC 62153-4-4 has been prepared by subcommittee 46A: Coaxial cables, of IEC technical committee 46: Cables, wires, waveguides, r.f. connectors, r.f. and microwave passive components and accessories.

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

FDIS	Report on voting
46A/799/FDIS	46A/816/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.

IEC 62153 consists of the following parts under the general title *Metallic communication cable test methods:*

Part 1-1: Electrical – Measurement of the pulse/step return loss in the frequency domain using the Inverse Discrete Fourier Transformation (IDFT)

Part 1-2: Reflection measurement correction[1]

Part 4-0: Electromagnetic Compatibility (EMC) – Relationship between Surface transfer impedance and Screening attenuation, recommended limits[1]

Part 4-1: Electromagnetic Compatibility (EMC) – Introduction to electromagnetic (EMC) screening measurements[1]

Part 4-2: Electromagnetic compatibility (EMC) – Screening and coupling attenuation – Injection clamp method

Part 4-3: Electromagnetic Compatibility (EMC) – Surface transfer impedance – Triaxial method

Part 4-4: Electromagnetic Compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation "as " up to and above 3 GHz

Part 4-5: Electromagnetic Compatibility (EMC) – Coupling or screening attenuation – absorbing clamp method

Part 4-6: Electromagnetic Compatibility (EMC) – Surface transfer impedance – line injection method

Part 4-7: Electromagnetic Compatibility (EMC) – Shielded screening attenuation, test method for measuring the Transfer impedance ZT, the screening attenuation as and the coupling attenuation ac of RF-Connectors up to and above 3 GHz; Tube in Tube method

Part 4-8: Electromagnetic Compatibility (EMC) – Capacitive Coupling Admittance [1]

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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

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1 Under consideration.

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-4: Electromagnetic compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation a_s up to and above 3 GHz

1 Scope

This part of IEC 62153 determines the screening attenuation a_S of metallic communication cable screens. Due to the concentric outer tube, measurements are independent of irregularities on the circumference and outer electromagnetic field.

A wide dynamic and frequency range can be applied to test even super-screened cables with normal instrumentation from low frequencies up to the limit of defined transversal waves in the outer circuit at approximately 4 GHz.

2 Normative references

The following referenced documents are indispensable for the application 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 61917:1998, *Cables, cable assemblies and connectors – Introduction to electromagnetic (EMC) screening measurements* [2]

3 Symbols and theoretical background

3.1 Electrical symbols

Z_1	characteristic impedance of the primary circuit (cable under test)
Z_2	characteristic impedance of the secondary circuit
Z_S	normalized value of the characteristic impedance of the environment of the cable under test (150 Ω outer circuit impedance Z_2)
R	input impedance of the receiver
Z_T	transfer impedance of the cable under test in Ω/m
$Z_F = Z_1 \times Z_2 \times j\omega \times C_T$	capacitive coupling impedance of the cable under test in Ω/m
f	frequency in Hz
C_T	through capacitance of the outer conductor per unit length in F/m
ε_{r1}	relative dielectric permittivity of the cable under test
ε_{r2}	relative dielectric permittivity of the secondary circuit
$\varepsilon_{r2,n}$	normalized value of the relative dielectric permittivity of the environment of the cable
l	effective coupling length

2 This is under revision and will be replaced by IEC 62153-4-1.

λ_o	vacuum wavelength
c_o	vacuum velocity
a_s	screening attenuation which is comparable to the results of the absorbing clamp method
a_{sn}	normalized screening attenuation (Z_S = 150 Ω and $\lvert\Delta v/v_1\rvert$ = 10 %)
P_1	feeding power of the primary circuit
P_2	measured power received on the input impedance R of the receiver in the secondary circuit
P_r	radiated power in the environment of the cable, which is comparable to $P_{2,n} + P_{2,f}$ of the absorbing clamp method
P_S	radiated power in the normalized environment of the cable under test (Z_S = 150 Ω and $\lvert\Delta v/v_1\rvert$ = 10 %)

$$\varphi_1 = 2\pi\left(\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right) l / \lambda_0$$

$$\varphi_2 = 2\pi\left(\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}\right) l / \lambda_0$$

$$\varphi_3 = \varphi_2 - \varphi_1 = 4\pi\sqrt{\varepsilon_{r2}}\, l / \lambda_0$$

3.2 Theoretical background

For exact calculation, if feedback from the secondary to the primary circuit is negligible, the ratio of the far-end voltages U_1 and U_2 are given by

$$\left|\frac{U_2}{U_1}\right| \approx \left|\frac{Z_T - Z_F}{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}} \times \left[1 - e^{-j\varphi_1}\right] + \frac{Z_T + Z_F}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}} \times \left[1 - e^{-j\varphi_2}\right]\right| \times \left|\frac{1}{\omega \cdot Z_1}\right| \times \left|\frac{c_0}{2 + (Z_2 / R - 1) \times \left(1 - e^{-j\varphi_3}\right)}\right| \quad (1)$$

i.e. formally **|** $A + B$ **|** $\times C \times D$, where AC is the far-end crosstalk, BC is the reflected near- end crosstalk and D is the mismatch factor.

The total oscillations of D are

<2 dB, if	$1 < Z_2/R < 1,25$
3 dB, if	$Z_2/R = 1,4$
but	10 dB and more, if $Z_2/R > 3$.
Maximum values of AC and BC are given, if	$\varphi_{1,2} = (2N + 1) \times \pi$ and N is an integer.

A more detailed description of the subject will be given in future IEC 62153-4-1 (which is intended to be a revision of IEC 61917).

3.3 Screening attenuation

The logarithmic ratio of the feeding power P_1 and the periodic maximum values of the power $P_{r,max}$ which may be radiated due to the peaks of voltage U_2 in the outer circuit is termed screening attenuation a_s.

$$a_{\mathrm{s}} = -10 \times \log_{10}\left(\mathrm{Env}\left|\frac{P_{\mathrm{r,max}}}{P_1}\right|\right) \quad (2)$$

The relationship of the radiated power P_{r} to the measured power P_2 received on the input impedance R is

$$\frac{P_{\mathrm{r}}}{P_2} = \frac{P_{\mathrm{r,max}}}{P_{\mathrm{2,max}}} = \frac{R}{2 \times Z_{\mathrm{S}}} \quad (3)$$

There will be a variation of the voltage U_2 on the far end, caused by the electromagnetic coupling through the screen and superimposition of the partial waves caused by the surface transfer impedance Z_{T}, the capacitive coupling impedance Z_{F} (travelling to the far and near end) and the totally reflected waves from the near end.

At high frequencies and when the cable under test is electrically long:

$$\sqrt{\left|\frac{P_{\mathrm{2,max}}}{P_1}\right|} \approx \frac{c_{\mathrm{o}}}{\omega\sqrt{Z_1 \times R}} \times \left|\frac{Z_{\mathrm{T}} - Z_{\mathrm{F}}}{\sqrt{\varepsilon_{\mathrm{r1}}} - \sqrt{\varepsilon_{\mathrm{r2}}}} + \frac{Z_{\mathrm{T}} + Z_{\mathrm{F}}}{\sqrt{\varepsilon_{\mathrm{r1}}} + \sqrt{\varepsilon_{\mathrm{r2}}}}\right| \quad (4)$$

3.4 Relationship between length and the surface transfer impedance Z_{T}

The relationship between the effective coupling length of the cable under test and the electrical wave length is important for the characteristic curve of the screening attenuation (see Figures 1 and 2). In the frequency range of electrically short coupling lengths, the measured attenuation decreases with increasing length. Therefore, it is necessary to define the related length.

With electrically long lengths the screening attenuation formed by the maximum envelope curve to the coupling voltage ratio is constant for a 6 dB/octave increasing transfer impedance. Therefore, the screening attenuation is defined only at high frequencies.

The coupling length is electrically short, if

$$\lambda_{\mathrm{o}}/l > 10 \times \sqrt{\varepsilon_{\mathrm{r1}}} \quad \text{or} \quad f < \frac{c_{\mathrm{o}}}{10 \times l \times \sqrt{\varepsilon_{\mathrm{r1}}}} \quad (5)$$

or electrically long, if

$$\lambda_{\mathrm{o}}/l \leq 2 \times \left|\sqrt{\varepsilon_{\mathrm{r1}}} - \sqrt{\varepsilon_{\mathrm{r2}}}\right| \quad \text{or} \quad f > \frac{c_{\mathrm{o}}}{2 \times l \times \left|\sqrt{\varepsilon_{\mathrm{r1}}} - \sqrt{\varepsilon_{\mathrm{r2}}}\right|} \quad (6)$$

where

l	is the effective coupling length in metres (approximately 2 m in Figure 3);
λ_{o}	is the free space wavelength in metres;
$\varepsilon_{\mathrm{r1}}$	is the resulting relative permittivity of the dielectric of the cable;
$\varepsilon_{\mathrm{r2}}$	is the resulting relative permittivity of the dielectric of the secondary circuit;
f	is the frequency in Hz.

The measured voltage ratio is related to the transfer impedance Z_T for electrically short coupling length by

$$Z_T \times l \approx Z_1 \times \left|\frac{U_2}{U_1}\right| \tag{7}$$

Also, at high frequencies, Z_T can be calculated if Z_F is negligible

$$Z_T \approx \left|\frac{\omega \times \sqrt{Z_1 \times R} \times |\varepsilon_{r1} - \varepsilon_{r2}|}{2 \times c_o \times \sqrt{\varepsilon_{r1}}} \times \sqrt{\left|\frac{P_{2max}}{P_1}\right|}\right| \tag{8}$$

therefore

$$\sqrt{\left|\frac{P_{2max}}{P_1}\right|} \approx \left|\frac{Z_T \times 2 \times c_o \times \sqrt{\varepsilon_{r1}}}{\omega \times \sqrt{Z_1 \times R} \times |\varepsilon_{r1} - \varepsilon_{r2}|}\right| \tag{9}$$

A more detailed description of the subject will be given in future IEC 62153-4-0 (which is intended to be a revision of IEC 61196-1:1995, Amendment 1:1999, Clause 14).

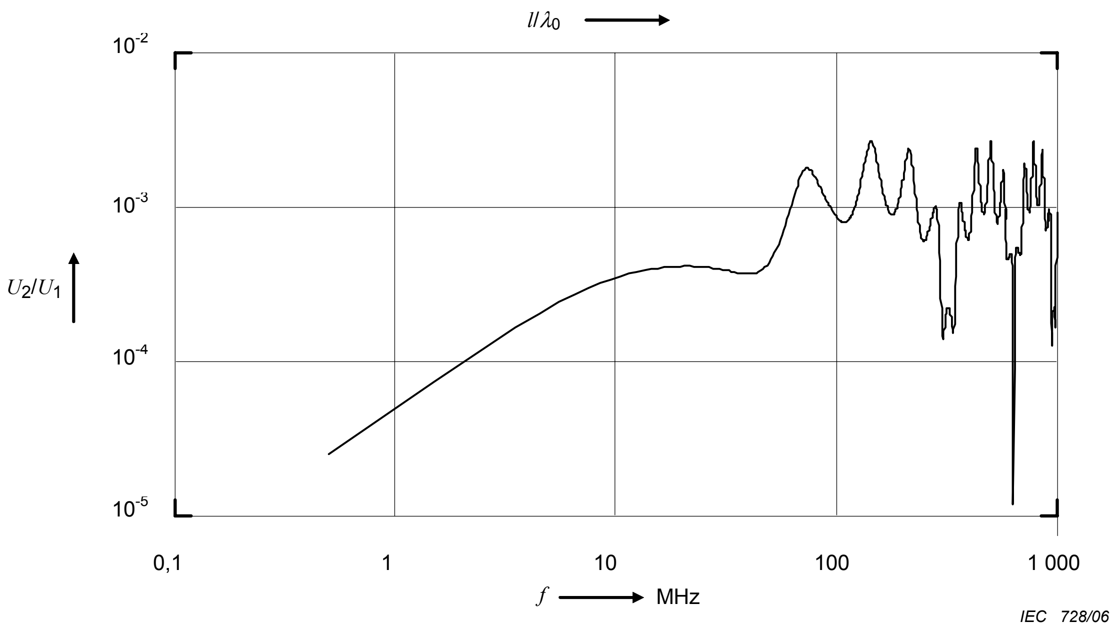

Figure 1 – Relationship of U_2/U_1 on a log (f) scale for a single braided cable

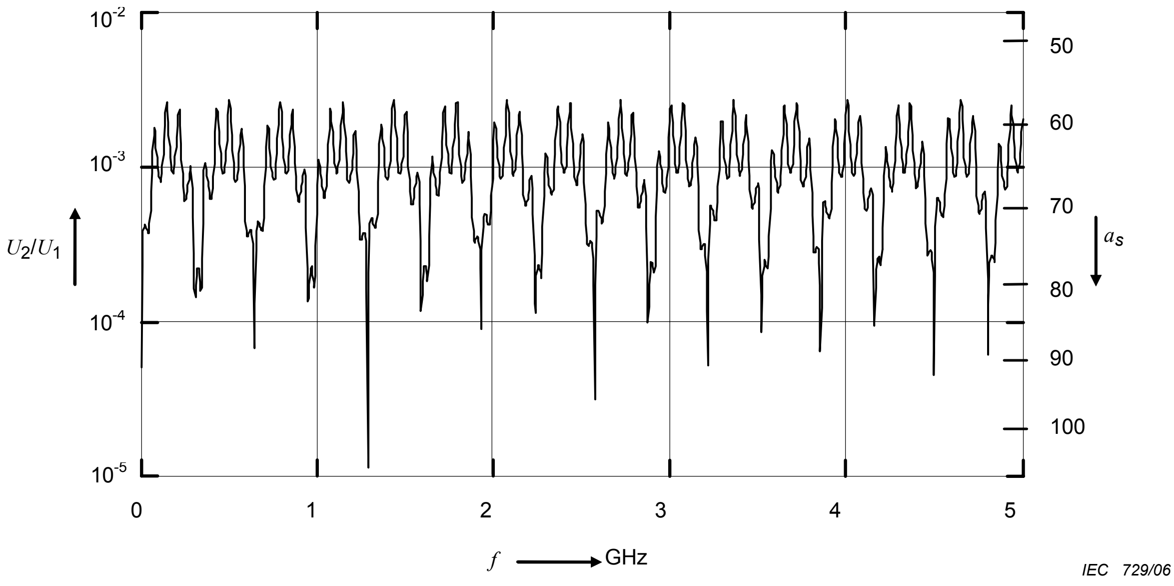

Figure 2 – Relationship of U_2/U_1 on a linear (f) scale and screening attenuation a_s on a linear (f) scale for a single braided cable

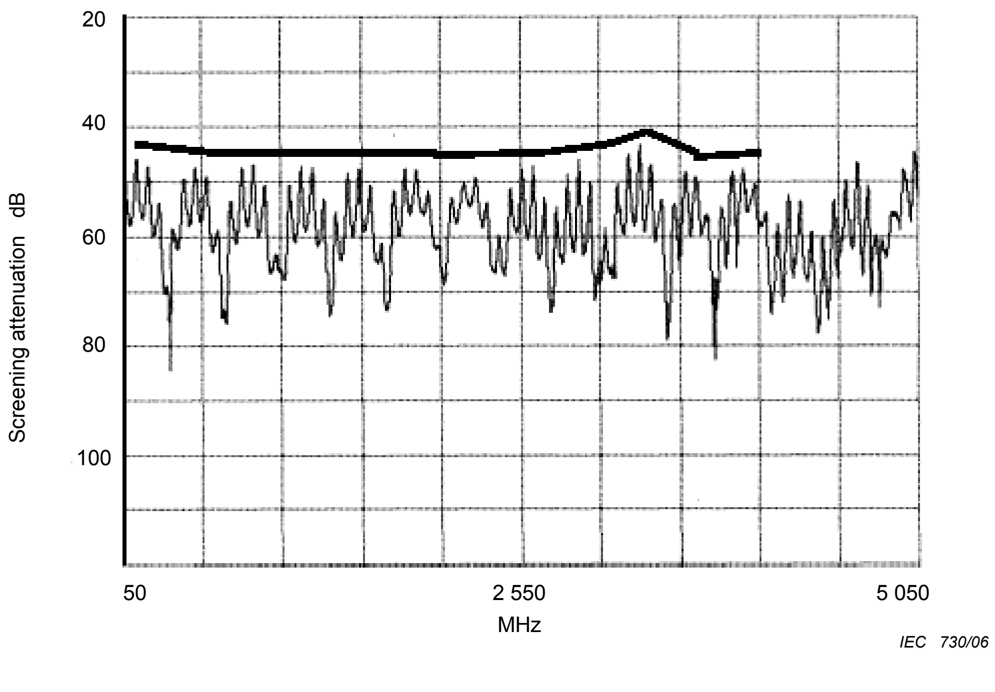

Figure 3 – Measured screening attenuation a_s formed by the maximum envelope curve to the measured coupling voltage ratio U_2/U_1 of a single braided cable

4 Principles of the measuring method

The disturbing or primary circuit is the matched cable under test. The disturbed or secondary circuit consists of the outer conductor (or the outermost layer in the case of multiscreen cables) of the cable under test and a solid metallic tube having the cable under test in its axis (see Figures 4 and 5).

The voltage peaks at the far end of the secondary circuit have to be measured. The near end of the secondary circuit is short-circuited. For this measurement, a matched receiver is not necessary. The expected voltage peaks at the far end are not dependent on the input impedance of the receiver, provided that it is lower than the characteristic impedance of the secondary circuit. However, it is an advantage to have a low mismatch, for example, by selecting a range of tube diameters for several sizes of coaxial cables.

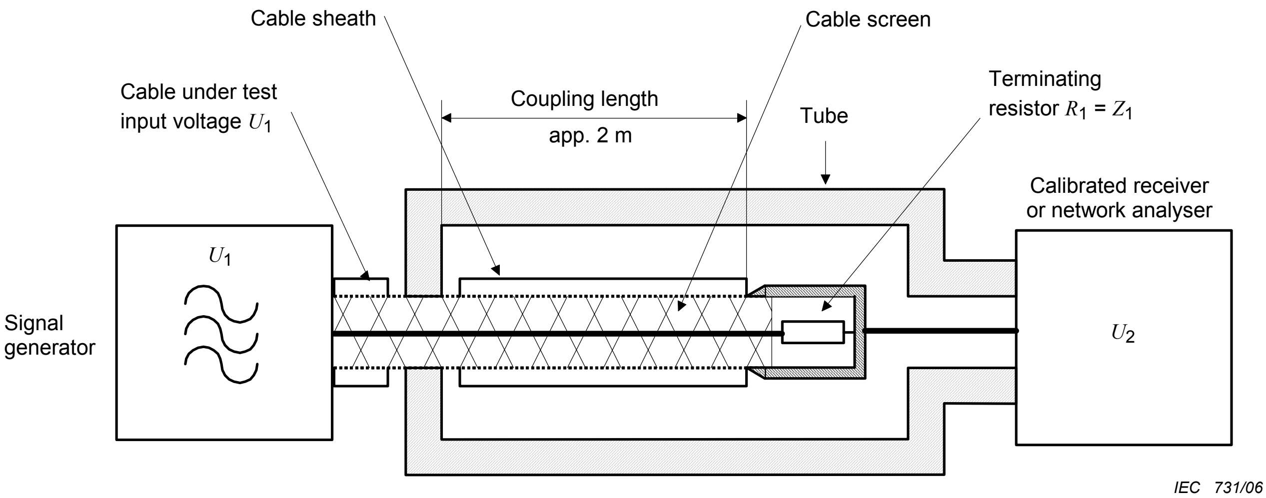

Figure 4 – Triaxial measuring set-up

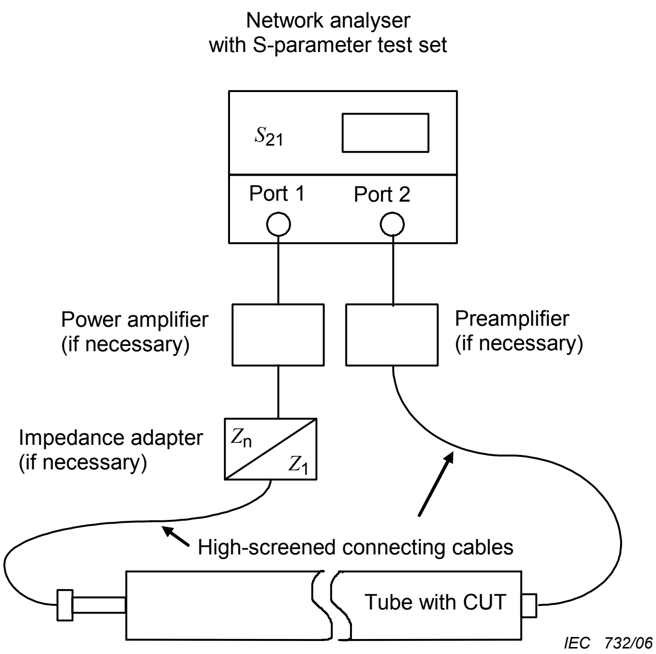

Figure 5 – Triaxial measuring set-up connected to the network analyser

5 Measurement

5.1 Equipment

The measuring set-up is shown in Figures 4 and 5 and consists of

- an apparatus of a triple coaxial form with a length sufficient to produce a superimposition of waves in narrow frequency bands which enable the envelope curve to be drawn;
- commonly, a coupling length of 2 m is preferable to determine the screening attenuation from less than 50 MHz upwards. The cylindrical cable screen forms both the outer conductor of the energized coaxial system and the inner conductor of the outer system. The outer conductor of the outer system is a tube of about 50 mm inner diameter with a short circuit to the screen on the fed side of the cable. The ratio of the inner diameter of the tube to the outer diameter of the screen must be sufficient to ensure that the characteristic impedance is larger than the input resistance of the receiver. The value of the relative dielectric permittivity of the outer circuit shall be approximately one, irrespective of the enclosing cable sheath;
- a signal generator with the same characteristic impedance as the cable under test or with an impedance adapter, completed by a power amplifier if necessary for very high screening attenuation;
- a receiver with a calibrated step attenuator or network analyser.

5.2 Cable under test

5.2.1 Coaxial cables

The cable sample is terminated at the far end by a very well screened resistance equal to the nominal value of the characteristic impedance. The connections between the terminating resistance, the screening cap and the cable screen shall be made with care so that the contact resistance can be neglected when interpreting the results. Special care shall be taken in preparing foil screens in order to avoid cracks in the foil which may introduce errors in the test results.

On the fed side, the cable screen is connected to the short-circuit disc of the outer tube, and care shall be taken so that the contact resistance is small and does not influence the results.

The cable under test shall be positioned as nearly concentric as possible in the outer tube to obtain homogeneous wave propagation.

5.2.2 Symmetrical and multiconductor cables

5.2.2.1 General

Screened symmetrical and multiconductor cables are treated as a quasi-coaxial system. Therefore, the conductors of all pairs shall be connected together at both ends. All screens, also those of individually screened pairs or quads, shall be connected together at both ends. The screens shall be connected over the whole circumference (see Figure 6).

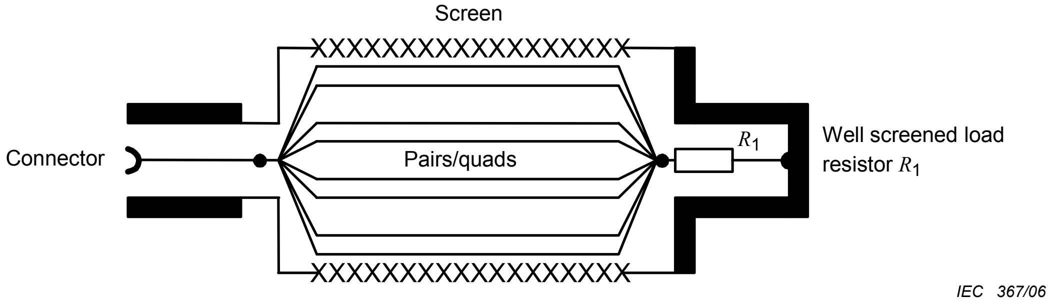

Figure 6 – Preparation of test sample (symmetrical and multi-conductor cables)

The quasi-coaxial system shall be terminated with its nominal characteristic impedance. The termination shall be well screened, so that the test results are not falsified. (The screening of the matching load shall be better than the screen under test).The impedance of the quasi-coaxial system can either be measured by using a TDR with maximum 200 ps risetime or using the method described in 5.2.2.2. Furthermore, an impedance matching adapter is necessary to match the impedance of the generator and the impedance of the quasi-coaxial system.

5.2.2.2 Impedance of inner system

One end of the prepared sample is connected to a network analyser, which is calibrated for impedance measurements at the connector interface reference plane. The test frequency shall be the approximate frequency for which the length of the sample is 1/8 λ, where λ is the wavelength.

$$f_{\text{test}} \approx \frac{c}{8.L_{\text{sample}} \times \sqrt{\varepsilon_{r1}}}$$

where

f_{test} is the test frequency;

c is the velocity of light, 3×10^8 m/s;

L_{sample} is the length of the sample.

The sample is short-circuited at the far end. The impedance Z_{short} is measured.

The sample is left open at the same point where it was shorted. The impedance Z_{open} is measured.

The impedance of the quasi-coaxial system Z_1 is calculated as

$$Z_1 = \sqrt{Z_{\text{short}} \times Z_{\text{open}}}$$

5.2.2.3 Z_1 <50 Ω

If the impedance of the inner system Z_1 and subsequently the load resistor R_1 is less than 50 Ω (the generator impedance), the formulas given below are used.

$$R_s = 50\sqrt{1-\frac{R_1}{50}}$$

$$R_p = \frac{R_1}{\sqrt{1-\frac{R_1}{50}}}$$

The configuration is depicted in Figure 7.

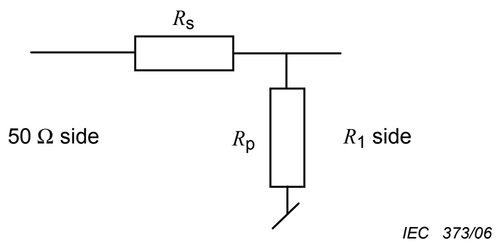

Figure 7 – Impedance matching for Z_1 <50 Ω

The voltage gain k_m of the circuit is

$$k_m = \frac{R_1 R_p}{R_1 R_p + R_p R_s + R_1 R_s}$$

5.2.2.4 Z_1 >50 Ω

If the impedance of the inner system Z_1 and subsequently R_1 is greater than 50 Ω (the generator impedance), the formulas given below are used.

$$R_s = R_1 \sqrt{1 - \frac{50}{R_1}}$$

$$R_p = \frac{50}{\sqrt{1 - \frac{50}{R_1}}}$$

The configuration is depicted in Figure 8.

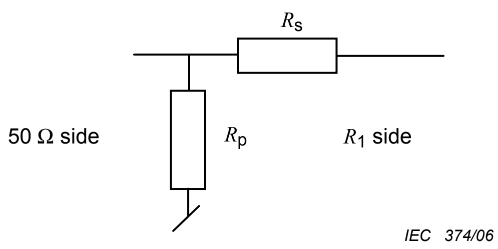

Figure 8 – Impedance matching for Z_1 >50 Ω

The voltage gain, k_m of the circuit is

$$k_m = \frac{R_1}{R_s + R_1}$$

5.3 Procedure

The quotient of the voltages at the output of the outer circuit and the input of the cable is measured, either directly by a network analyser or with a calibrated step attenuator (assuming that the receiver has the same input impedance as the output impedance of the signal generator ($R = Z_1$)) which is inserted as an alternative to the triaxial apparatus.

Only the peak values of the maximum of the voltage ratio or the minimum of the attenuation must be measured and recorded as a function of the frequency in order to determine the envelope curve.

The attenuation introduced by the inclusion of adapters, instead of direct connection, shall be taken into account when calibrating the triaxial apparatus.

The voltage ratio measured is not dependent on the diameter of the outer tube of the triaxial test set-up or on the characteristic impedance Z_2 of the outer system, provided that Z_2 is larger than the input impedance of the receiver.

5.4 Expression of results

5.4.1 Screening attenuation

The screening attenuation a_S which is comparable to the results of the absorbing clamp method shall be calculated with the normalized value Z_S = 150 Ω.

$$a_S = 10 \times \log_{10} \left| \frac{P_1}{P_{r,max}} \right| = 10 \times \log_{10} \left| \frac{P_1}{P_{2,max}} \times \frac{2 \times Z_S}{R} \right|$$

$$= 20 \times \log_{10} \left| \frac{U_1}{U_{2,max}} \right| + 10 \times \log_{10} \left| \frac{300\Omega}{Z_1} \right|$$

$$= a_{m,min} - a_Z + 10 \times \log_{10} \left| \frac{300\Omega}{Z_1} \right| \qquad (10)$$

where

a_S is the screening attenuation related to the radiating impedance of 150 Ω in dB;

$a_{m,min}$ is the attenuation recorded as minimum envelope curve of the measured values in dB;

a_Z is the additional attenuation of an eventually inserted adapter, if not otherwise eliminated, for example, by the calibration, in dB);

U_1 is the input voltage of the primary circuit formed by the cable in V;

U_2 is the output voltage of the secondary circuit in V;

Z_1 is the characteristic impedance of the cable under test in Ω.

At frequencies lower than the limit of the electrically long coupling length, the measurement will be similar to that for surface transfer impedance.

5.4.2 Normalized screening attenuation

The screening attenuation is dependent on the velocity difference between the inner and outer circuit. Therefore, the test results may also be presented in normalized conditions where Z_S = 150 Ω and the velocity difference is 10 %.

$$a_{s,n} = a_s + \Delta a \tag{11}$$

where $a_{s,n}$ is the normalized screening attenuation.

$$a_{s,n} = 20 \times \log_{10} \left| \frac{\omega \times \sqrt{Z_1 \times Z_s} \times \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2,n}} \right|}{Z_T \times c_0} \right| \tag{12}$$

where

a_S is the screening attenuation;

Z_1 is the characteristic impedance of the primary circuit;

Z_S is a normalized value of the characteristic impedance of the environment of the cable under test, $Z_S = 150\ \Omega$;

Z_T is the transfer impedance of the cable under test;

ε_{r1} is the relative dielectric permittivity of the cable under test;

$\varepsilon_{r2,n}$ is a normalized value of the relative dielectric permittivity of the environment of the cable.

The difference between the normalized screening attenuation and the measured screening attenuation is calculated by

$$\Delta a = 20 \times \log_{10} \left(\sqrt{2} \times \frac{\left| 1 - \sqrt{\frac{\varepsilon_{r2,n}}{\varepsilon_{r1}}} \right|}{\left| 1 - \frac{\varepsilon_{r2,t}}{\varepsilon_{r1}} \right|} \right) \tag{13}$$

where $\varepsilon_{r2,t} \approx 1{,}1$ is the relative dielectric permittivity of the outer circuit (tube) during the measurement.

With respect to the velocity difference, $\Delta v/v_1 = 10\ \%$ the relation between $\varepsilon_{r2,n}$ and ε_{r1} is

$$\sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r2,n}}} = 1{,}1 \tag{14}$$

Therefore, for both solid PE and foamed PE dielectric of the cable with $\varepsilon_{r1} \approx 2{,}3$ and $\varepsilon_{r1} \approx 1{,}6$ respectively

$$\Delta a \approx -10\ \text{dB} \tag{15}$$

6 Requirement

The results of minimum screening attenuation shall comply with the value indicated in the relevant cable specification.

If a limiting value of the radiating power is specified for a cable system operated with a defined power level, the difference between the power level and the limit of radiating power shall not be greater than the screening attenuation of the cable provided for the system.

Bibliography

IEC 62153-4-0, *Metallic communication cable test methods – Part 4-0: Electromagnetic Compatibility (EMC) – Relationship between Surface transfer impedance and Screening attenuation, recommended limits* [3]

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[3] Under consideration. Future IEC 62153-4-0 is intended to be the revision of IEC 61196-1:1995, Amendment 1:1999, clause 14.

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A Prioritaire

Non affrancare
No stamp required

RÉPONSE PAYÉE

SUISSE

Customer Service Centre (CSC)
International Electrotechnical Commission
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1211 GENEVA 20
Switzerland

Q1 Please report on **ONE STANDARD** and **ONE STANDARD ONLY**. Enter the exact number of the standard: *(e.g. 60601-1-1)*

....

Q2 Please tell us in what capacity(ies) you bought the standard *(tick all that apply).* I am the/a:

- purchasing agent ❑
- librarian ❑
- researcher ❑
- design engineer ❑
- safety engineer ❑
- testing engineer ❑
- marketing specialist ❑
- other...

Q3 I work for/in/as a: *(tick all that apply)*

- manufacturing ❑
- consultant ❑
- government ❑
- test/certification facility ❑
- public utility ❑
- education ❑
- military ❑
- other...

Q4 This standard will be used for: *(tick all that apply)*

- general reference ❑
- product research ❑
- product design/development ❑
- specifications ❑
- tenders ❑
- quality assessment ❑
- certification ❑
- technical documentation ❑
- thesis ❑
- manufacturing ❑
- other...

Q5 This standard meets my needs: *(tick one)*

- not at all ❑
- nearly ❑
- fairly well ❑
- exactly ❑

Q6 If you ticked NOT AT ALL in Question 5 the reason is: *(tick all that apply)*

- standard is out of date ❑
- standard is incomplete ❑
- standard is too academic ❑
- standard is too superficial ❑
- title is misleading ❑
- I made the wrong choice ❑
- other ....

Q7 Please assess the standard in the following categories, using the numbers:
(1) unacceptable,
(2) below average,
(3) average,
(4) above average,
(5) exceptional,
(6) not applicable

- timeliness ....
- quality of writing....................................
- technical contents.................................
- logic of arrangement of contents ....
- tables, charts, graphs, figures...............
- other ....

Q8 I read/use the: *(tick one)*

- French text only ❑
- English text only ❑
- both English and French texts ❑

Q9 Please share any comment on any aspect of the IEC that you would like us to know:

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ISBN 2-8318-8633-3

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ICS 33.120.10; 33.100

Typeset and printed by the IEC Central Office
GENEVA, SWITZERLAND