IEC 62153-4-9

Edition 2.0 2018-05

INTERNATIONAL STANDARD

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colour inside

**Metallic communication cable test methods –
Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method**

**Méthodes d'essais des câbles métalliques de communication –
Partie 4-9: Compatibilité électromagnétique (CEM) – Affaiblissement de couplage des câbles symétriques écrantés, méthode triaxiale**

IEC 62153-4-9:2018-05(en-fr)

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METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method

FOREWORD

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International Standard IEC 62153-4-9 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 2008. This edition constitutes a technical revision.

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

– two test procedures, open head and standard head procedure;
– measuring with balun or with multiport respectively mixed mode VNA;
– extension of frequency range up to and above 2 GHz.

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

FDIS	Report on voting
46/681/FDIS	46/685/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 can be found, under the general title *Metallic communication cable test methods*, 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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method

1 Scope

This part of IEC 62153 applies to metallic communication cables. It specifies a test method for determining the coupling attenuation a_C of screened balanced cables. Due to the concentric outer tube, measurements are independent of irregularities on the circumference and external electromagnetic fields.

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. However, when using a balun, the upper frequency is limited by the properties of the balun.

Measurements can be performed with standard tube procedure (respectively with standard test head) according to IEC 62153-4-4 or with open tube (open test head) procedure.

The procedure described herein to measure the coupling attenuation a_C is based on the procedure to measure the screening attenuation a_S according to IEC 62153-4-4.

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 – Chapter 726: Transmission lines and waveguides*

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

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

IEC 62153-4-4, *Metallic communication cable test methods – Part 4-4: Electromagnetic compatibility (EMC) – Test method for measuring of the screening attenuation as up to and above 3 GHz, triaxial method*

IEC 62153-4-5, *Metallic communication cables test methods – Part 4-5: Electromagnetic compatibility (EMC) – Coupling or screening attenuation – Absorbing clamp method*

3 Terms, definitions and symbols

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

a_s is the screening attenuation which is comparable to the results of the absorbing clamp method in dB;

a_c is the coupling attenuation related to the radiating impedance of 150 Ω in dB;

a_u is the unbalanced attenuation;

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

a_z is the additional attenuation of a possible inserted adapter, if not otherwise eliminated e.g. by the calibration, in dB;

C_T is the through capacitance of the outer conductor in F/m;

c_0 is the vacuum velocity in m/s;

dx is the differential length operator of integration;

λ_0 is the vacuum wavelength in m;

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

ε_{r2} is the relative dielectric permittivity of the secondary circuit;

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

f is the frequency in Hz;

j is the imaginary operator (square root of minus one);

L is the transmission line parameter-inductance;

l is the effective coupling length in m;

φ is a phase factor in the ratio of the secondary to primary circuit end voltages (U_1/U_2);

P_1 is the feeding power of the primary circuit in W;

P_2 is the measured power received on the input impedance;

R of the receiver in the secondary circuit in W;

P_r is the radiated power in the environment of the cable, which is comparable to P_{2n} + P_{2f} of the absorbing clamp method in W;

$P_{r,max}$ is the periodic maximum value of the common mode radiated power in W;

P_s is the radiated power in the normalised environment of the cable under test,

(Z_s = 150 Ω and $|\Delta v / v_1|$ = 10 %) in W,

$$\varphi_1 = 2\pi \times \left(\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right) \times l / \lambda_0 \tag{1}$$

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

$$\varphi_3 = \varphi_2 - \varphi_1 = 4\pi \times \sqrt{\varepsilon_{r2}} \times l / \lambda_0 \tag{3}$$

R is the input impedance of the receiver in Ω;

R_{DM} is the differential mode termination, Ω;

S is the summing function;

T is the coupling transfer function;

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;

Ω is the radian frequency ω;

Z_1 is the (differential mode) characteristic impedance of the cable under test (primary circuit) in Ω;

Z_2 is the characteristic impedance of the secondary circuit in Ω;

Z_{com} is the common mode (unbalanced);

Z_{diff} is the nominal characteristic impedance of the differential mode (balanced);

Z_F is the capacitive coupling impedance of the cable under test in Ω/m,

$$Z_F = Z_1 \cdot Z_2 \cdot j \cdot 2 \cdot \pi \cdot f \cdot C_T \quad (4)$$

Z_S is the normalised value of the characteristic impedance of the environment of the cable;

Z_T is the transfer impedance of the cable under test in Ω/m;

4 Principle of the measuring method

4.1 General

Coupling attenuation of screened balanced cables describes the overall effect against electromagnetic interference (EMI) taking into account both the unbalance attenuation of the pair and the screening attenuation of the screen.

The disturbing circuit (the inner or primary circuit) consists of the test cable which is fed by a generator and is impedance-matched at the near and far ends. The disturbed circuit (the outer or secondary circuit) is formed by the solid metallic tube and the short section of the cable under test covered by the tube. The disturbed circuit (the outer or secondary circuit) is terminated at the near end in a short circuit and is terminated at the far end with a calibrated receiver or network analyser.

The voltage peaks at the far end of the secondary circuit are measured with a calibrated receiver or network analyser. For this measurement a matched receiver is not necessary. These voltage peaks are not dependant on the input impedance of the receiver, provided that the input impedance of the receiver is lower than the characteristic impedance of the secondary circuit. However, it is advantageous to have a low mismatch, for example by selecting a range of tube diameters for several cable sizes.

To measure the coupling attenuation as well as to measure the unbalance attenuation a differential signal is required. This can, for example, be generated using a balun which converts the unbalanced signal of a 50 Ω network analyser into a balanced signal.

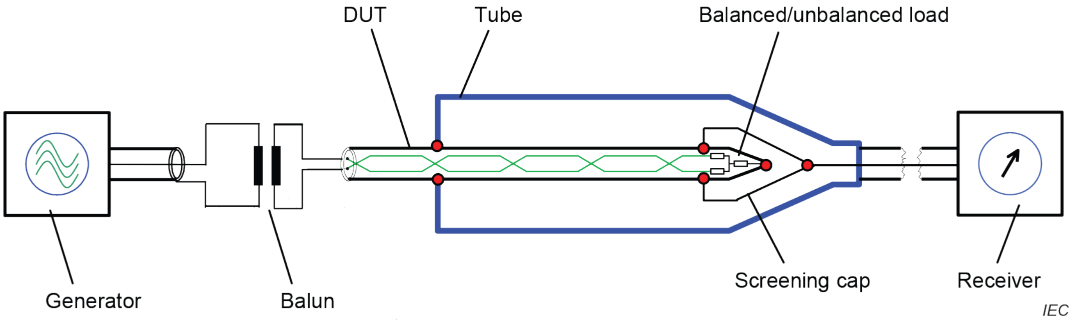


Figure 1 – Coupling attenuation, principle test set-up with balun and standard tube

Alternatively, a balanced signal may be obtained by using a vector network analyser (VNA) having two generators with a phase shift of 180°. Another alternative is to measure with a multi-port VNA (virtual balun). The properties of balanced pairs are determined mathematically from the measured values of each single conductor of the pair against reference ground. The coverable frequency range for the determination of the reflection and transmissions characteristics of symmetrical pairs is no longer limited by the balun but by the VNA and the connection technique.

A detailed definition of mixed mode S-parameters for measurements with virtual balun is given in Annex B.

The test set-up (see Figures 1, 2, 3 and 4) is a triaxial system consisting of an outer solid metallic tube in which the cable under test (CUT) is concentrically positioned.

At the near end, the screen of the screened cable under test is short circuited with the solid metallic tube.

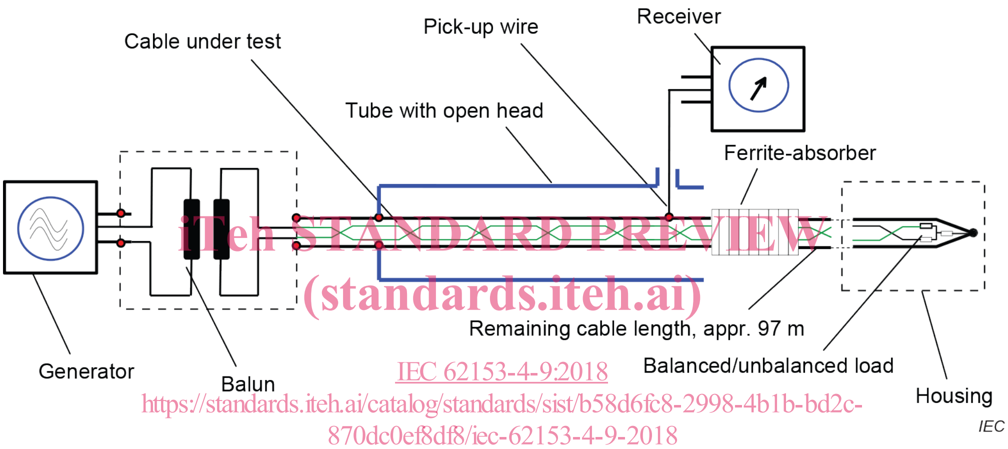


Figure 2 – Coupling attenuation, principle test set-up with balun and open head

At the far end, the tube can be equipped with a "test head" which can be removed from the tube for easier connecting of the CUT. The set-up according to IEC 62153-4-4 is designated as the standard procedure, respectively the procedure with standard head. The advantage is an overall closed and shielded set-up.

Alternatively, the tube can be equipped with an open head at the far end (see Figures 2 and 4).

4.2 Procedure A: measuring with standard tube (standard head)

The set-up detailed in Procedure A uses the standard test-head and is in principle the same as described in IEC 62153-4-4. The screened balanced DUT can be fed either in common mode or in differential mode. In this way, both, screening attenuation of the screen or coupling attenuation of the screened pair can be measured. In principle, with the same set-up, also the transfer impedance of the screen can be measured (taking into account the length of the DUT).

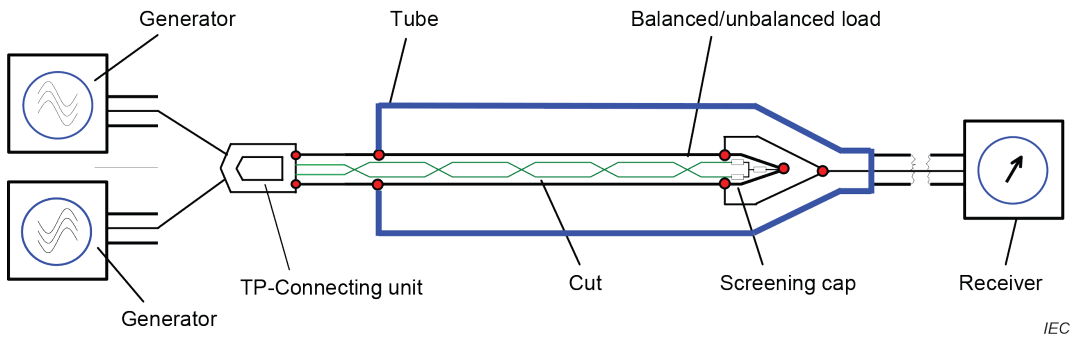


Figure 3 – Coupling attenuation, principle set-up with multiport VNA and standard head

The DUT shall be matched at the far end in common and differential mode. Return loss of the CUT in common and differential mode shall be measured. Values for return loss in common and differential mode shall be at least 10 dB.

4.3 Procedure B: measuring with open head

In case of measuring with open head the first several meters of a longer length of the cable to be tested are concentrically positioned in an outer solid metallic tube. The remaining length (usually of 100 m length) that extends past the tube is placed in a highly shielded box and terminated with common mode and differential mode terminations (see Figure 6). The cable screen shall be connected with low impedance to the screened box. The center point of the differential mode termination shall be connected via the resistor R_{CM} to the highly screened box or cable screen (see Figure 6).

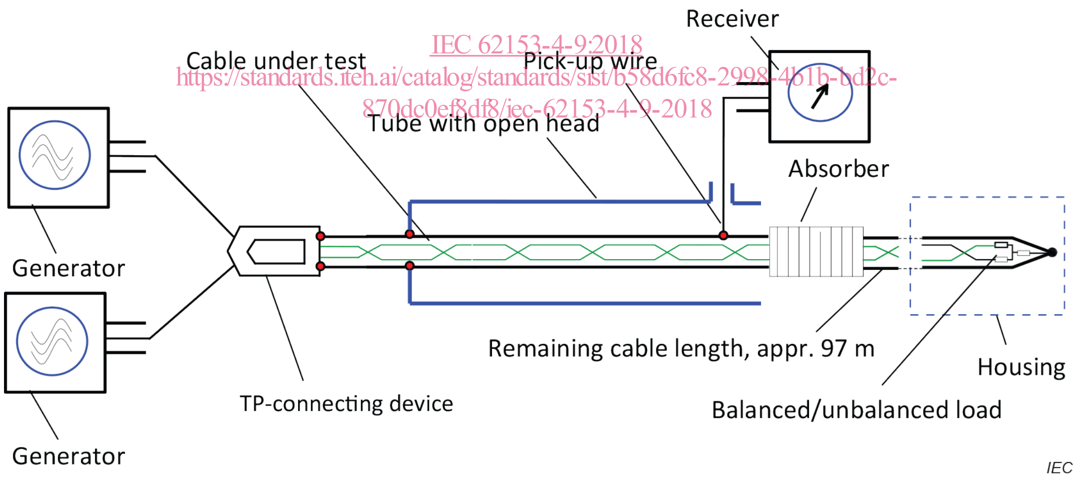


Figure 4 – Coupling attenuation, principle set-up with multiport VNA and open head

At the near end, the screen of the screened cable under test is short circuited with the solid metallic tube.

At the far end, the tube is let open and the signal is picked up by a “pick up wire”, which is connected to the screen of the cable under test (see Figure 4). The open tube system can also be equipped with a “test head” which can be removed from the tube for easier connecting of the CUT.

At the open end of the tube, absorbers shall be applied to match the system and to avoid back travelling waves into the system. The attenuation of the absorber shall be at least 20 dB. A combination of a ferrite absorber and/or nanocrystalline absorber may be used. A procedure to measure the attenuation of absorbers is given in Annex A.

5 Screening parameters

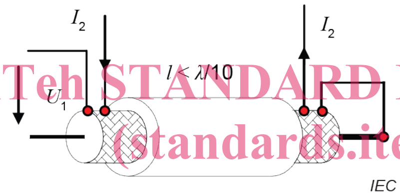
5.1 General

To protect a cable against external electromagnetic interference or to avoid radiation into the environment, the cable is surrounded with screens made of metal foils and/or braids. For cables used in harsh electromagnetic environments, elaborate shield structures, made of several layers or magnetic materials, are also used. In case of balanced cables, also the overall symmetry of the pair contributes to the screening effectiveness in addition to the screen.

The sole effect of the screen is described by the transfer impedance and the screening attenuation. The influence of the symmetry is grasped by the unbalance attenuation. The overall effect of the screen and the symmetry of the pair (for balanced cables) are described by the coupling attenuation.

5.2 Transfer impedance

For an electrically short screen, the transfer impedance Z_T is defined as the quotient of the longitudinal voltage U_1 induced to the inner circuit by the current I_2 fed into the outer circuit or vice versa, related to length in Ω/m or in mΩ/m (see Figure 5).



$$Z_T = \frac{U_1}{I_2 \cdot l} \quad (5)$$

Figure 5 – Definition of transfer impedance

The test procedure for transfer impedance is described in IEC 62153-4-3. According to the definition it can be measured on short cable samples.

5.3 Screening attenuation

The screening attenuation a_s is the measure of the effectiveness of a cable screen. It is the logarithmic ratio of the feeding power P_1 to the maximum radiated power $P_{r,max}$.

With the arbitrary determined normalized value Z_S = 150 Ω (see IEC 62153-4-4) one gets:

$$a_s = 10 \cdot \lg \left| \frac{P_1}{P_{r,max}} \right| = 10 \cdot \lg \left| \frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_S}{R} \right| \text{ dB} \quad (6)$$

$$a_s = 20 \cdot \lg \left| \frac{U_1}{U_{2,max}} \right| + 10 \cdot \lg \left[\frac{2 \cdot Z_S}{Z_1} \right] \text{ dB} \quad (7)$$

whereas R is the input impedance of the receiver. More details are given in IEC TS 62153-4-1 and in IEC 62153-4-4.

With the arbitrary determined normalized value Z_S = 150 Ω one gets for screened balanced cables (in the common mode) the screening attenuation a_s:

$$a_s = 10 \cdot \lg \left| \frac{P_{com}}{P_{r,max}} \right| \text{ dB} \tag{8}$$

$$a_s = 20 \cdot \lg \left| \frac{U_{com}}{U_{2,max}} \right| + 10 \cdot \lg \left[\frac{2 \cdot Z_S}{Z_{com}} \right] \text{ dB} \tag{9}$$

5.4 Unbalance attenuation

Screened balanced pairs may be operated in two different modes: the differential mode (balanced) and the common mode (unbalanced). In the differential mode one conductor carries the current $+I$ and the other conductor carries the current $-I$; the screen is without current. In the common mode, both conductors of the pair carry half of the current $+I/2$, and the screen is the return path with the current $-I$, comparable to a coaxial cable.

Under ideal conditions respectively with ideal cables, both modes are independent from each other. However under real conditions, both modes influence each other.

The unbalance attenuation a_u of a pair describes in logarithmic scale how much power couples from the differential mode to the common mode and vice versa. It is the logarithmic ratio of the input power in the differential mode P_{diff} to the power which couples to the common mode P_{com} [8][1].

$$a_u = 10 \cdot \lg \left| \frac{P_{diff}}{P_{com}} \right| \text{ dB} \tag{10}$$

$$= 20 \cdot \lg \left| \frac{U_{diff}}{U_{com}} \right| + 10 \cdot \lg \left[\frac{Z_{com}}{Z_{diff}} \right] \text{dB} \tag{11}$$

Differences in the resistance of the conductors, in the diameter of the core insulation, in the core capacitance, unequal twisting and different distances of the cores to the screen are some reasons for the unbalance of the pair.

At low frequencies, the unbalance attenuation decreases with increasing cable length. At higher frequencies and/or length, the unbalance attenuation approaches asymptotic to a maximum value – similar to the screening attenuation – depending on the type of cable and its distribution of the inhomogeneity along the cable length. Unbalance attenuation may be determined for the near end as well as for the far end of the cable [5].

5.5 Coupling attenuation

The coupling attenuation of screened balanced pairs describes the global effect against electromagnetic interference (EMI) and takes into account both the effect of the screen and the symmetry of the pair.

1 Figures in square brackets refer to the Bibliography.

6 Measurement

6.1 General

Measurements can be performed with a two-port VNA and balun (see Figures 1 and 2) or with multiport or mixed mode VNA and connecting unit (see Figures 3 and 4) both with standard tube, respectively with standard test head, or with open test head procedure.

6.2 Equipment

To measure the coupling attenuation, as well as to measure the unbalance attenuation, a differential signal is required. This can, for example, be generated using a balun which converts the unbalanced signal of a 50 Ω network analyser into a balanced (usually 100 Ω) signal.

Alternatively, a balanced signal may be obtained by using a vector network analyser (VNA) having two generators with a phase shift of 180°. Another alternative is to measure with a multi-port VNA (virtual balun). The properties of balanced pairs are determined mathematically from the measured values of each single conductor of the pair against reference ground. The coverable frequency range for the determination of the reflection and transmissions characteristics of symmetrical pairs is no longer limited by the balun, but by the VNA and the connection technique.

A detailed description of mixed mode parameters is given in Annex C.

The measurement set-ups are shown in Figures 1 to 4 and consist of:

- a metallic non ferromagnetic tube with a length sufficient to produce a superimposition of waves in narrow frequency bands which enable the envelope curve to be drawn; the test head of the tube may be standard head according to IEC 62153-4-4 (Figures 1 and 3) or open head (Figures 2 and 4)

- a two port network analyser when measuring with balun (a separate generator and receiver may also be used);
- a balun for impedance matching of an unbalanced generator output signal to the characteristic impedance of balanced cables; or
- a Twisted Pair (TP)-connecting unit when measuring with multiport respectively with mixed mode VNA;
- absorber rings (ferrite or nanocrystalline) with an attenuation a_{absorber} > 20 dB in the measured frequency range when using the open head method;
- metallic boxes to shield the balun and the remaining cable length including the matching resistors when using the open test head method.

6.3 Balun requirements

A balun may be required to match the output impedance of the generator (a balun is not required when a balanced output generator is used) to the nominal characteristic impedance of the cable under test. The balun performance requirements are specified in Table 1.

The attenuation of the balun shall be kept as low as possible because it will limit the dynamic range of the coupling attenuation measurements.