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INTERNATIONAL STANDARD

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Metallic communication cable test methods –
Part 4-9: Electromagnetic compatibility (EMC) related test method for measuring coupling attenuation of screened balanced cables – Triaxial method

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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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This consolidated version of the official IEC Standard and its amendments has been prepared for user convenience.

IEC 62153-4-9 edition 2.2 contains the second edition (2018-05) [documents 46/681/FDIS and 46/685/RVD], its amendment 1 (2020-07) [documents 46/773/FDIS and 46/776/RVD] and its amendment 2 (2024-06) [documents 46/990/FDIS and 46/1002/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

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 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.

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 and its amendments will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION to Amendment 1

The goal of this amendment is to extent IEC 62153-4-9 such that also the coupling attenuation of unscreened single or multiple balanced pairs or unscreened quads can be measured with the triaxial test procedure.

Further complement is the extension of the usable frequency range down to frequencies below 9 kHz to measure the low frequency coupling attenuation of screened and unscreened balanced pairs or quads.

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,

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

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

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

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.

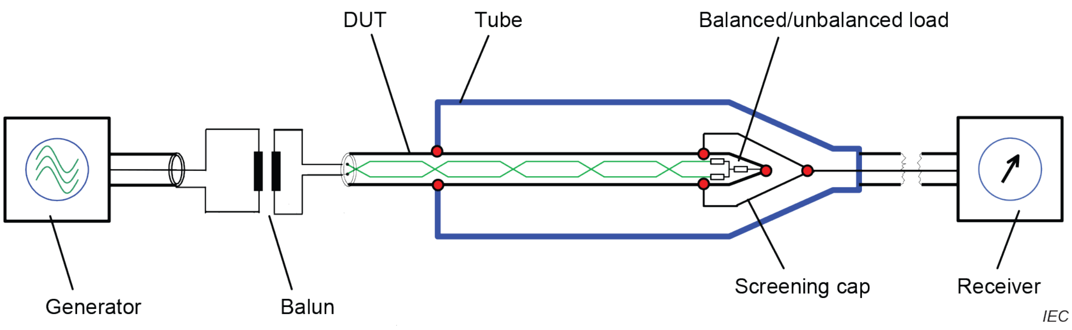

Figure 1 – Coupling attenuation, principle test set-up with balun and standard tube

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.

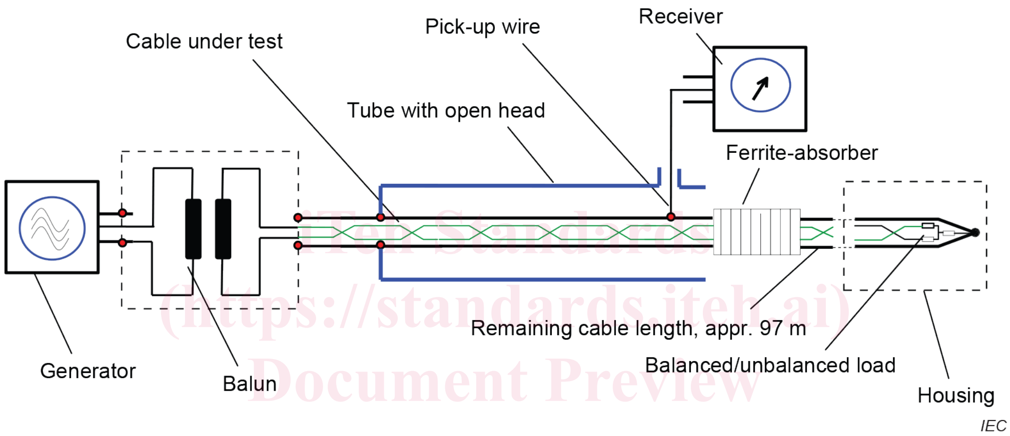

Figure 2 – Coupling attenuation, principle test set-up with balun and open head

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).

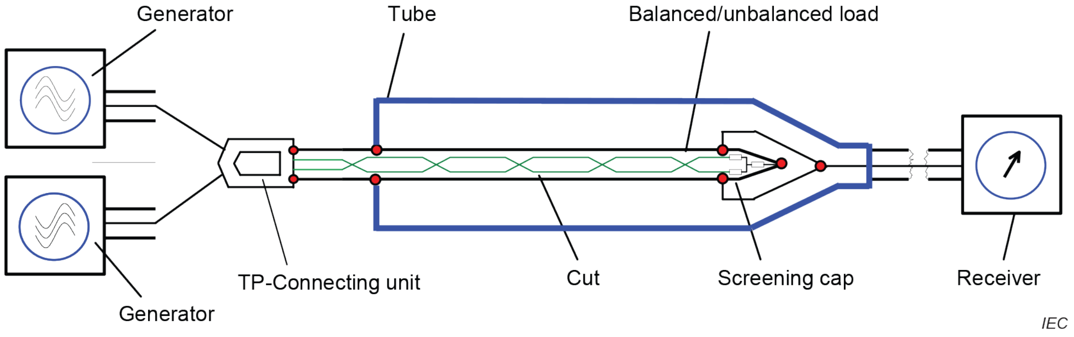

Figure 3 – Coupling attenuation, principle set-up with multiport VNA and standard head

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).

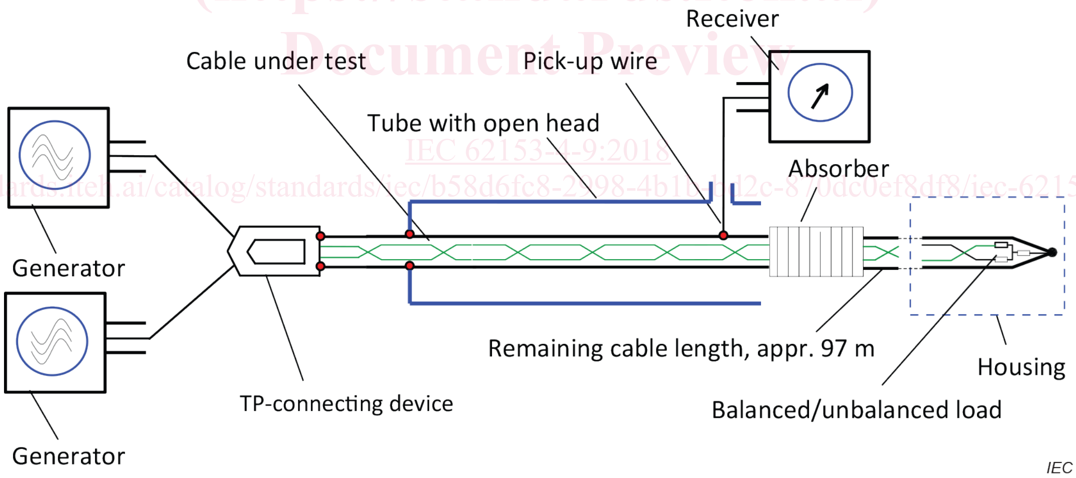

Figure 4 – Coupling attenuation, principle set-up with multiport VNA and open head

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.