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TECHNICAL REPORT

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

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METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic (EMC) screening measurements

FOREWORD

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IEC/TR 62153-4-1, which is a technical report, has been prepared by IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

This publication cancels and replaces IEC/TR 61917, published in 1998.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
46/199/DTR	46/253/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the 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- withdrawn,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.

INTRODUCTION

Screening is one basic way of achieving electromagnetic compatibility (EMC). However, a confusingly large number of methods and concepts is available to test for the screening quality of cables and related components, and for defining their quality.

IEC/TR 62153-4-1 provides a brief introduction to basic concepts and terms trying to reveal the common features of apparently different test methods. It should assist in correct interpretation of test data, and in the better understanding of screening (or shielding) and related specifications and standards.

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic (EMC) screening measurements

1 Scope

IEC/TR 62153-4-1, which is a technical report, gives a brief introduction to basic concepts and terms that reveal the common features of various test methods.

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 60096-4-1:1990, *Radio-frequency cables – Part 4: Specification for superscreened cables – Section 1: General requirements and test methods*

IEC 60169-1-3:1988, *Radio frequency connectors – Part 1: General requirements and measuring methods – Section 3: Electrical tests and measuring procedures – Screening effectiveness*

IEC 61196-1:2005, *Coaxial communication cables – Part 1: Generic specification – General, definitions and requirements – Second edition*

IEC 61726: *Cable assemblies, cables, connectors and passive microwave components – Screening attenuation measurement by the reverberation chamber method*

IEC 62153-4-2, *Metallic communication cables test methods – Part 4-2: Electromagnetic compatibility (EMC) – Screening and coupling attenuation – Injection clamp method*

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

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

IEC 62153-4-7, *Metallic communication cables test methods – Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring the transfer impedance and the screening – or the coupling attenuation – Tube in tube method*

IEC 62153-4-9, *Metallic communication cable test methods – Part 4-9: Electromagnetic Compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method*[1]

EN 50289-1-6, *Communication cables – Specification for test methods – Electrical test methods – Electromagnetic performance*

[1] To be published.

3 List of symbols

a_s	screening attenuation
a_{sn}	normalized screening attenuation with phase velocity difference not greater than 10 % and 150 Ω characteristic impedance of the injection line
c	velocity of light
C_T	through capacitance of the braided cable
CUT	cable or component under test
E	EMF
f	frequency
f	far end
f_c	cut-off frequency
f_{cf}	far end cut-off frequency
f_{cn}	near end cut-off frequency
Φ_1	the total flux of the magnetic field induced by the disturbing current I_1
Φ'_{12}	the direct leaking magnetic flux
Φ''_{12}	complete magnetic flux in the braid
I_1, U_1	current and voltage in the primary circuit (feeding system)
I_F	current coupled by the feed through capacitance to the secondary system (measuring system)
ε_{r1}	relative permittivity of the injection line (feeding system)
ε_{r2}	relative permittivity of the cable (measuring system)
l	cable length
L_1	(external) inductance of the outer circuit
L_2	(external) inductance of the inner circuit
M'_{12}	mutual inductance related to direct leakage of the magnetic flux Φ'_{12}
M''_{12}	mutual inductance related to the magnetic flux Φ''_{12} (or ½ Φ''_{12}) in the braid

$$M'_{12} = \frac{\Phi'_{12}}{j\omega I_1} \quad \text{and} \quad M''_{12} = \frac{1}{2}\cdot\frac{\Phi''_{12}}{j\omega I_1}$$

n	near end
P_1	sending power
P_{2f}	far end measured power
P_{2n}	near end measured power
T	coupling transfer function
T_f	far end transfer function

T_n near end transfer function

$$T_{n,f} = T_{\genfrac{}{}{0pt}{}{n}{f}}$$

U'_2 the disturbing voltage induced by Φ'_{12}

U''_{rh} the disturbing voltage induced by ½ Φ''_{12} of the right hand lay contribution

U''_{lh} the disturbing voltage induced by ½ Φ''_{12} of the left hand lay contribution

U''_2 is equal to U''_{rh} and U''_{lh} (= the disturbing voltage induced by ½ Φ''_{12})

v phase velocity

v_1 phase velocity of the "primary" system (feeding system)

v_2 phase velocity of the "secondary" system (measuring system)

v_{r1} relative phase velocity of the "primary" system (feeding system)

v_{r2} relative phase velocity of the "secondary" system (measuring system)

Z_1 characteristic impedance of the "primary" system (feeding system or line (1))

Z_2 characteristic impedance of the cable under test (CUT) (measuring system or line (2))

Z_{1f} terminating impedance of the line (1) in the far end

Z_{2n} terminating impedance of the line (2) in the near end

Z_{2f} terminating impedance of the line (2) in the far end (in a matched set-up

$Z_{1f} = Z_1$ and $Z_{2n} = Z_{2f} = Z_2$)

$$Z_{12} = \sqrt{Z_1 Z_2}$$

Z_a surface impedance of the braided cable

Z_F capacitive coupling impedance per unit length

Z_f capacitive coupling impedance

Z_T surface transfer impedance per unit length

Z_{Th} transfer impedance of a tubular homogeneous screen per unit length

Z_t surface transfer impedance

Z_{TEn} effective transfer impedance (= | $Z_F + Z_T$ |) per unit length in the near end

Z_{TEf} effective transfer impedance (= | $Z_F - Z_T$ |) per unit length in the far end

$Z_{TEn,f}$ effective transfer impedance (= | $Z_F \pm Z_T$ |) per unit length in the near end or in the far end

Z_{TE} effective transfer impedance (= max | Z_{TEn}, Z_{TEf} |) per unit length

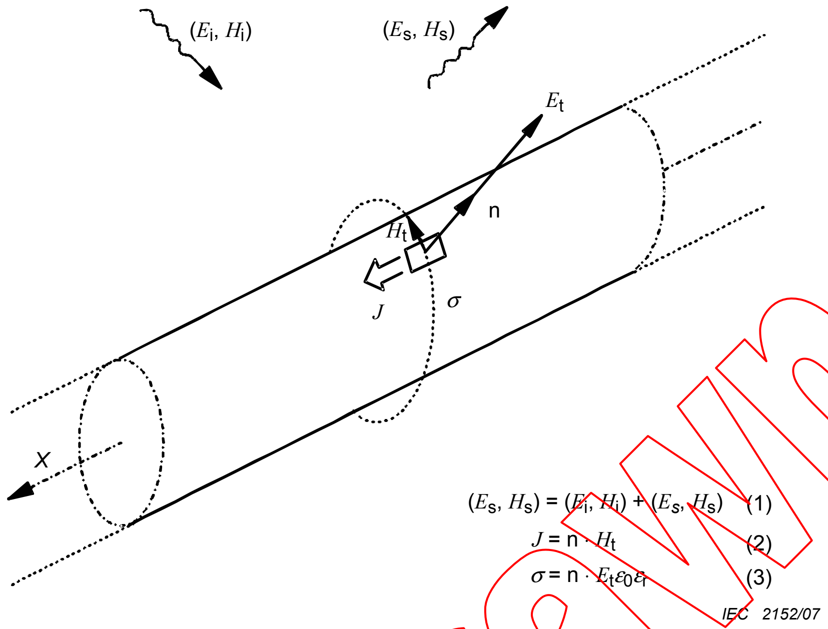
Z_{te} effective transfer impedance (= max | $Z_f \pm Z_t$ |)

Z_{ten} normalized effective transfer impedance of a cable (Z_1 = 150 Ω and | $v_1 - v_2$ | / $v_2 \leq$ 10 % velocity difference in relation to velocity of CUT

4 Electromagnetic phenomena

It is assumed that if an electromagnetic field is incident on a screened cable, there is only weak coupling between the external field and that inside, and that the cable diameter is very small compared with both the cable length and the wavelength of the incident field. The superposition of the external incident field and the field scattered by the cable yields the total electromagnetic field (E_t, H_t, in Figure 1). The total field at the screen's surface may be considered as the source of the coupling: the electric field penetrates through apertures by *electric* or capacitive coupling; also magnetic fields penetrate through apertures by *inductive* or magnetic coupling.

Additionally, the induced current in the screen results in *conductive* or resistive coupling.

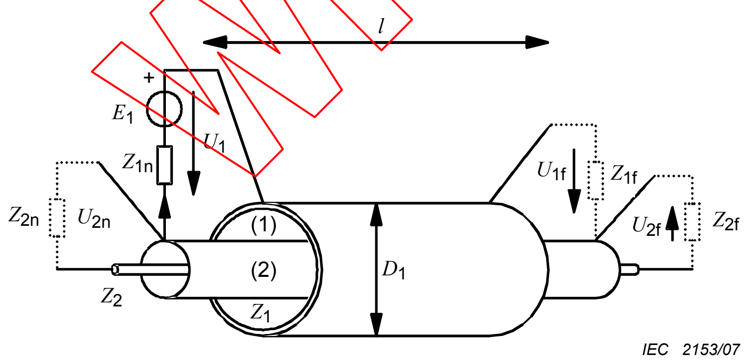


Key

n unit vector normal to surface

Figure 1 – Incident (i), scattered (s) and resulting total electromagnetic fields (E_t, H_t) with induced surface current- and charge- densities J (A/m) and σ (C/m²)

As the field at the surface of the screen is directly related to density of surface current and surface charge, the coupling may be assigned either to the total field (E_t, H_t) or to the surface current- and charge- densities (J and σ). Consequently, the coupling can be simulated into the cable by reproducing through any means the surface currents and charges on the screen. Because a cable of small diameter is assumed, higher modes can be neglected and an additional coaxial conductor can be used as the injection structure, as shown in Figure 2.



Concept of a triaxial set-up

1) Outer circuit, formed by injection cylinder and screen, characteristic impedance Z_1,

2) Inner circuit, formed by a screen, and centre conductor, characteristic impedance Z_2; screening at the ends not shown.

Conditions Z_{1f}, Z_{2n}, Z_{2f} and λ are observed in Figure 3a and Figure 3b.

NOTE 1 $D_1 << l$.

NOTE 2 Both ends of circuit (2) must be well screened.

Figure 2 – Defining and measuring screening parameters – Triaxial set-up

5 Intrinsic screening parameters of short cables

The *intrinsic parameters* refer to an infinitesimal length of cable, like the inductance or capacitance per unit length of transmission lines. Assuming *electrically short cables*, with $l << \lambda$ which will always apply at low frequencies, the intrinsic screening parameters are defined and can be measured as follows:

5.1 Surface transfer impedance, Z_T

As shown in Figure 2 and Figure 3a (where Z_{1f} and Z_{2f} are zero):

$$Z_T = U_2 / I_1 \cdot l) \qquad (\Omega/\text{m}) \qquad (4)$$

The dependence of Z_T on frequency is not simple and is often shown by plotting log Z_T against log frequency. Note that the phase of Z_T may have any value, depending on braid construction and frequency range.

NOTE In circuit 2 of Figure 3a the voltmeter and short-circuit can be interchanged.

5.2 Capacitive coupling admittance, Y_c

As shown in Figure 2 and Figure 3b (where Z_{1f} and Z_{2f} are open circuit):

$$Y_C = j\omega C_T = I_2 / (U_1 \cdot l) \qquad (\text{mho/m}) \qquad (5)$$

The through capacitance (C_T) is a real capacitance and has usually a constant value up to 1 GHz and higher (with aperture $a << \lambda$).

While Z_T is independent of the characteristics of the coaxial circuits, C_T is dependent on those characteristics. There are two ways of overcoming this dependence:

a) The *normalized through elastance* K_T derived from C_T is independent of the size of the outer coaxial circuit, but it depends on its permittivity:

$$K_T = C_T / (C_1 C_2) \qquad (\text{m/F}) \qquad K_T \sim 1/(\varepsilon_{r1} + \varepsilon_{r2}) \qquad (6)\ (7)$$

where C_1 and C_2 are the capacitance per unit length of the two coaxial circuits.

b) The *capacitive coupling impedance* Z_F again derived from C_T is also independent of the size of the outer coaxial circuit and, for practical values of ε_{r1}, is only slightly dependent on its permittivity:

$$Z_F = Z_1 Z_2 Y_C = Z_1 Z_2 j\omega C_T \quad (\Omega/\text{m}) \quad Z_F \sim \sqrt{(\varepsilon_{r1} \cdot \varepsilon_{r2})} / (\varepsilon_{r1} + \varepsilon_{r2}) \qquad (8)\ (9)$$

Compared with Z_T, Z_F is usually negligible, except for open weave braids. It may, however, be significant when Z_{2n} and $Z_{2f} >> Z_2$ (audio circuits).