

## TECHNICAL REPORT

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

IEC TR 62153-4-1:2007

<https://standards.iteh.ai/catalog/standards/iec/a986e826-8dbd-4b3e-b8d2-ee0eed3bccae/iec-tr-62153-4-1-2007>



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2007 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Email: [inmail@iec.ch](mailto:inmail@iec.ch)  
Web: [www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: [www.iec.ch/online\\_news/justpub](http://www.iec.ch/online_news/justpub)

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: [www.iec.ch/webstore/custserv](http://www.iec.ch/webstore/custserv)

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: [csc@iec.ch](mailto:csc@iec.ch)

Tel.: +41 22 919 02 11

Fax: +41 22 919 03 00

IEC TR 62153-4-1:2007

<https://standards.iec.org/standards/iec/a986e826-8dbd-4b3e-b8d2-ee0ced3bccae/iec-tr-62153-4-1-2007>

# TECHNICAL REPORT

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

IEC TR 62153-4-1:2007

<https://standards.iteh.ai/catalog/standards/iec/a986e826-8dbd-4b3e-b8d2-ee0ced3bccae/iec-tr-62153-4-1-2007>

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

PRICE CODE

**XA**

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 List of symbols.....	9
4 Electromagnetic phenomena.....	10
5 Intrinsic screening parameters of short cables.....	12
5.1 Surface transfer impedance, $Z_T$ .....	12
5.2 Capacitive coupling admittance, $Y_C$ .....	12
5.3 Injecting with arbitrary cross-sections.....	14
5.4 Reciprocity and symmetry.....	14
5.5 Arbitrary load conditions.....	14
6 Long cables – Coupled transmission lines.....	14
7 Transfer impedance of a braided-wire outer conductor or screen.....	20
8 Test possibilities.....	26
8.1 Measuring the transfer impedance of coaxial cables.....	26
8.2 Measuring the transfer impedance of cable assemblies.....	27
8.3 Measuring the transfer impedance of connectors.....	27
8.4 Calculated maximum screening level.....	27
9 Comparison of frequency response of different triaxial test set-ups to measure transfer impedance of cable screens.....	32
9.1 Introductory remark.....	32
9.2 Physical basics.....	32
9.3 Simulations.....	35
9.4 Conclusion.....	49
Bibliography.....	50
Additional reading.....	51

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 $\sigma$ (C/m <sup>2</sup> ).....	11
Figure 2 – Defining and measuring screening parameters – Triaxial set-up.....	11
Figure 3a – Equivalent circuit for the definition and possible testing of $Z$ .....	13
Figure 3b – Equivalent circuit for the definition and possible testing of $Y_C = j \omega C_T$ .....	13
Figure 3c – Definition of electrical quantities in a set-up that is matched at all ends.....	13
Figure 3 – Defining and measuring screen parameters – Equivalent circuits.....	13
Figure 4 – Summing function $S\{l \cdot f\}$ for near (n) and far (f) end coupling.....	17
Figure 5a – Transfer impedance of a typical single braid screen.....	18
Figure 5b – Coupling transfer function for the same cable with negligible $Z_F$ ( $Z_F \ll Z_T$ ): frequency responses of Figure 4 and Figure 5a added on log scale.....	18
Figure 5 – The effect of the summing function.....	18

Figure 6 – The effects of the $Z_T$ and $Z_F$ to the coupling transfer functions $T_n$ and $T_f$ .....	19
Figure 7 – $l \times S$ : complete length dependent factor in the coupling function $T$ (see Table 1) .....	20
Figure 8 – Transfer impedance of typical cables .....	21
Figure 9a – Complete flux .....	21
Figure 9b – Left-hand lay contribution .....	21
Figure 9c – Right-hand lay contribution .....	21
Figure 9 – Magnetic coupling in the braid .....	21
Figure 10a – Complex plane, $Z_T = \text{Re } Z_T + j \text{Im } Z_T$ , frequency $f$ as parameter .....	22
Figure 10b – Magnitude (amplitude), $ Z_T(f) $ .....	23
Figure 10 – Measured transfer impedance $Z_T$ (d.c. resistance $Z_T$ (d.c.) set to the value of 10 mΩ/m .....	23
Figure 11a – Overbraided cable .....	24
Figure 11b – Underbraided cable .....	24
Figure 11 – Typical $Z_T$ (time) step response of an overbraided and underbraided single braided outer conductor of a coaxial cable .....	24
Figure 12a – Contributions to the transfer impedance .....	25
Figure 12b – Significant elements of circuits (1) and (2) .....	25
Figure 12 – $Z_T$ equivalent circuits of a braided-wire screen .....	25
Figure 13 – Example of visualization of the maximum measurable screening level .....	28
Figure 14 – Triaxial set-up for the measurement of the transfer impedance $Z_T$ .....	32
Figure 15 – Equivalent circuit of the triaxial set-up .....	32
Figure 16 – Simulation of frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 2,3$ (solid PE), $\epsilon_{r2} = 1,0$ , $n = 0,659$ .....	37
Figure 17 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 1,6$ (foam PE), $\epsilon_{r2} = 1,0$ , $n = 0,791$ .....	37
Figure 18 – Simulation of frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 1,3$ (foam PE), $\epsilon_{r2} = 1,0$ , $n = 0,877$ .....	38
Figure 19 – Simulation of frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 5$ (PVC), $\epsilon_{r2} = 1,0$ , $n = 0,447$ .....	38
Figure 20 – Simulation of the 3 dB cut off wavelength ( $L/\lambda_1$ ) as a function of factor $n = \sqrt{\epsilon_{r2}}/\sqrt{\epsilon_{r1}}$ given for different factors $v = Z_2/R_{2,f}$ .....	39
Figure 21 – Interpolation of the simulated 3 dB cut off wavelength ( $L/\lambda_1$ ) as a function of factor $n = \sqrt{\epsilon_{r2}}/\sqrt{\epsilon_{r1}}$ given for different factors $v = Z_2/R_{2,f}$ .....	39
Figure 22 – 3 dB cut-off frequency length product as a function of dielectric permittivity of the inner circuit (cable) given for different factors $v = Z_2/R_{2,f}$ .....	40
Figure 23 – Measurement result of the normalized voltage drop of a single braid screen in the triaxial set-up for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 2,3$ (PE), $\epsilon_{r2} = 1,0$ , $n = 0,659$ , $Z_2 = 130 \Omega$ , $L = 1 \text{ m}$ .....	41
Figure 24 – Measurement result of the normalized voltage drop of a single braid screen in the triaxial set-up for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 1,6$ (foam PE), $\epsilon_{r2} = 1,0$ , $n = 0,791$ , $Z_2 = 130 \Omega$ , $L = 1 \text{ m}$ .....	41
Figure 25 – Triaxial set-up (measuring tube), double short-circuited method .....	42
Figure 26 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 2,3$ (solid PE), $\epsilon_{r2} = 1,0$ , $n = 0,659$ .....	43
Figure 27 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\epsilon_{r1} = 1,6$ (foam PE), $\epsilon_{r2} = 1,0$ , $n = 0,791$ .....	43

Figure 28 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\varepsilon_{r1} = 1,3$ (foam PE), $\varepsilon_{r2} = 1,0$ , $n = 0,877$ .....	44
Figure 29 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\varepsilon_{r1} = 5$ (PVC), $\varepsilon_{r2} = 1,0$ , $n = 0,447$ .....	44
Figure 30 – Interpolation of the simulated 3 dB cut-off wavelength ( $L/\lambda_1$ ) as a function of factor $n = \sqrt{\varepsilon_{r2}}/\sqrt{\varepsilon_{r1}}$ given for different factors $v = Z_2/R_{2,f}$ .....	45
Figure 31 – 3 dB cut-off frequency length product as a function of dielectric permittivity of the inner circuit (cable) given for different factors $v = Z_2/R_{2,f}$ .....	46
Figure 32 – Simulation of the frequency response for different factors of $v = Z_2/R_{2,f}$ with $\varepsilon_{r1} = 2,3$ (PE), $\varepsilon_{r2} = 5$ (PVC), $n = 1,474$ .....	47
Figure 33 – Interpolation of the simulated 3 dB cut off wavelength ( $L/\lambda_1$ ) as a function of factor $n = \sqrt{\varepsilon_{r2}}/\sqrt{\varepsilon_{r1}}$ given for $v = Z_2/R_{2,f} < 1$ .....	48
Figure 34 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable) given for different factors $n = \sqrt{\varepsilon_{r2}}/\sqrt{\varepsilon_{r1}}$ , $v = Z_2/R_{2,f} < 1$ .....	48
Table 1 – The coupling transfer function $T$ (coupling function) .....	16
Table 2 – Screening effectiveness of cable test methods for surface transfer impedance $Z_T$ ..	30
Table 3 – Load conditions of the different set-ups .....	34
Table 4 – Parameters of the different set-ups .....	36
Table 5 – Cut-off frequency length product .....	40
Table 6 – Typical values for factor $v$ , for an inner tube diameter of 40 mm and a generator output impedance of $50 \Omega$ .....	42
Table 7 – Cut-off frequency length product .....	45
Table 8 – Material combinations and factor $n$ .....	47
Table 9 – Cut-off frequency length product for some typical cables in the different set-ups .....	49

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## METALLIC COMMUNICATION CABLE TEST METHODS –

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

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

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.

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

IEC TR 62153-4-1:2007

<https://standards.iteh.ai/catalog/standards/iec/a986e826-8dbd-4b3e-b8d2-ee0eed3bccae/iec-tr-62153-4-1-2007>



## 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.

WithDrawn

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

IEC TR 62153-4-1:2007  
<https://standards.iteh.ai/catalog/standards/iec/a986e826-8dbd-4b3e-b8d2-ec0eed3bccae/iec-tr62153-4-1-2007>

## 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<sup>1</sup>*

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

---

<sup>1</sup> To be published.

### 3 List of symbols

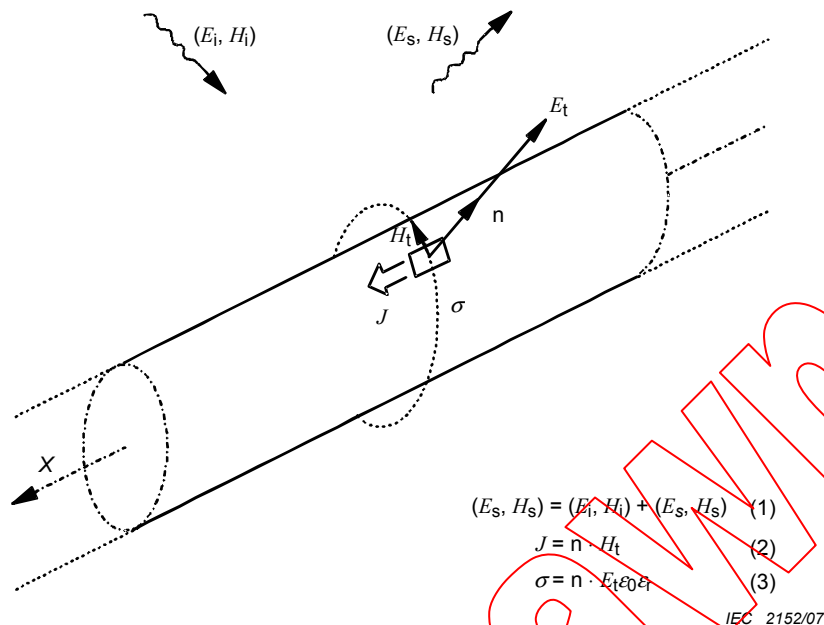
$a_s$	screening attenuation
$a_{sn}$	normalized screening attenuation with phase velocity difference not greater than 10 % and 150 $\Omega$ characteristic impedance of the injection line
$c$	velocity of light
$C_T$	through capacitance of the braided cable
CUT	cable or component under test
E	EMF
$f$	frequency
f	far end
$f_c$	cut-off frequency
$f_{cf}$	far end cut-off frequency
$f_{cn}$	near end cut-off frequency
$\Phi_1$	the total flux of the magnetic field induced by the disturbing current $I_1$
$\Phi'_{12}$	the direct leaking magnetic flux
$\Phi''_{12}$	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)
$\epsilon_{r1}$	relative permittivity of the injection line (feeding system)
$\epsilon_{r2}$	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 $\Phi'_{12}$
$M''_{12}$	mutual inductance related to the magnetic flux $\Phi''_{12}$ (or $\frac{1}{2} \Phi''_{12}$ ) 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
$T_{n,f} = T_n$	
$U'_2$	the disturbing voltage induced by $\Phi'_{12}$
$U''_{rh}$	the disturbing voltage induced by $\frac{1}{2} \Phi''_{12}$ of the right hand lay contribution
$U''_{lh}$	the disturbing voltage induced by $\frac{1}{2} \Phi''_{12}$ of the left hand lay contribution
$U''_2$	is equal to $U''_{rh}$ and $U''_{lh}$ (= the disturbing voltage induced by $\frac{1}{2} \Phi''_{12}$ )
$v$	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 ( $Z_1 = 150 \Omega$ 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.

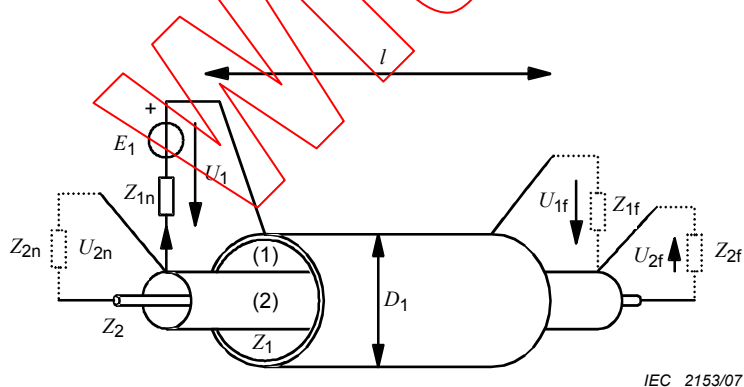


#### Key

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  $\sigma$  (C/m<sup>2</sup>)**

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  $\sigma$ ). 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  $\lambda$  are observed in Figure 3a and Figure 3b.

NOTE 1  $D_1 \ll l$ .

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  $l \ll \lambda$  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):

$$Z_T = U_2 / I_1 \cdot l \quad (\Omega/m) \quad (4)$$

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):

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

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

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:

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

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  $\epsilon_{r1}$ , is only slightly dependent on its permittivity:

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

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