



# TECHNICAL SPECIFICATION

---

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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

PRICE CODE **XD**

ICS 33.100

ISBN 978-2-8322-1311-7

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	7
1 Scope.....	9
2 Normative references .....	9
3 Symbols interpretation .....	10
4 Electromagnetic phenomena.....	12
5 The intrinsic screening parameters of short cables .....	14
5.1 General.....	14
5.2 Surface transfer impedance, $Z_T$ .....	14
5.3 Capacitive coupling admittance, $Y_C$ .....	14
5.4 Injecting with arbitrary cross-sections .....	16
5.5 Reciprocity and symmetry .....	16
5.6 Arbitrary load conditions .....	16
6 Long cables – coupled transmission lines .....	16
7 Transfer impedance of a braided wire outer conductor or screen .....	24
8 Test possibilities .....	30
8.1 General.....	30
8.2 Measuring the transfer impedance of coaxial cables .....	30
8.3 Measuring the transfer impedance of cable assemblies.....	31
8.4 Measuring the transfer impedance of connectors .....	31
8.5 Calculated maximum screening level .....	31
9 Comparison of the frequency response of different triaxial test set-ups to measure the transfer impedance of cable screens .....	36
9.1 General.....	36
9.2 Physical basics .....	36
9.2.1 Triaxial set-up.....	36
9.2.2 Coupling equations .....	38
9.3 Simulations .....	40
9.3.1 General .....	40
9.3.2 Simulation of the standard and simplified methods according to EN 50289-1-6, IEC 61196-1 (method 1 and 2) and IEC 62153-4-3 (method A) .....	40
9.3.3 Simulation of the double short circuited methods .....	46
9.4 Conclusion.....	54
10 Background of the shielded screening attenuation test method (IEC 62153-4-4).....	54
10.1 General.....	54
10.2 Objectives.....	55
10.3 Theory of the triaxial measuring method .....	55
10.4 Screening attenuation .....	60
10.5 Normalised screening attenuation .....	62
10.6 Measured results .....	63
10.7 Comparison with absorbing clamp method .....	65
10.8 Practical design of the test set-up .....	66
10.9 Influence of mismatches .....	67
10.9.1 Mismatch in the outer circuit .....	67
10.9.2 Mismatch in the inner circuit .....	69

11	Background of the shielded screening attenuation test method for measuring the screening effectiveness of feed-throughs and electromagnetic gaskets (IEC 62153-4-10).....	72
11.1	General.....	72
11.2	Theoretical background of the test Fixtures and their equivalent circuit.....	73
11.3	Pictures and measurement results .....	76
11.3.1	Characteristic impedance uniformity .....	76
11.3.2	Measurements of shielding effectiveness.....	78
11.3.3	Calculation of transfer impedance.....	80
11.4	Calculation of screening attenuation for feed-through when the transfer impedance $Z_T$ is known .....	82
12	Background of the shielded screening attenuation test method for measuring the screening effectiveness of RF connectors and assemblies (IEC 62153-4-7).....	83
12.1	Physical basics .....	83
12.1.1	Surface transfer impedance $Z_T$ .....	83
12.1.2	Screening attenuation $a_S$ .....	84
12.1.3	Coupling attenuation $a_C$ .....	84
12.1.4	Coupling transfer function.....	84
12.1.5	Relationship between length and screening measurements .....	85
12.2	Tube in tube set-up (IEC 62153-4-7) .....	86
12.2.1	General .....	86
12.2.2	Procedure.....	86
12.2.3	Measurements and simulations.....	88
12.2.4	Influence of contact resistances.....	89
	Bibliography.....	91
	Figure 1 – Total electromagnetic field $(\vec{E}_t, \vec{H}_t)$ .....	12
	Figure 2 – Defining and measuring screening parameters – A triaxial set-up.....	13
	Figure 3 – Equivalent circuit for the testing of $Z_T$ .....	15
	Figure 4 – Equivalent circuit for the testing of $Y_C = j \omega C_T$ .....	15
	Figure 5 – Electrical quantities in a set-up that is matched at both ends .....	16
	Figure 6 – The summing function $S\{L \cdot f\}$ for near and far end coupling .....	20
	Figure 7 – Transfer impedance of a typical single braid screen .....	20
	Figure 8 – The effect of the summing function on the coupling transfer function of a typical single braid screen cable .....	21
	Figure 9 – Calculated coupling transfer functions $T_n$ and $T_f$ for a single braid – $Z_F = 0$ .....	21
	Figure 10 – Calculated coupling transfer functions $T_n$ and $T_f$ for a single braid – $\text{Im}(Z_T)$ is positive and $Z_F = +0,5 \times \text{Im}(Z_T)$ at high frequencies.....	22
	Figure 11 – Calculated coupling transfer functions $T_n$ and $T_f$ for a single braid – $\text{Im}(Z_T)$ is negative and $Z_F = -0,5 \times \text{Im}(Z_T)$ at high frequencies.....	23
	Figure 12 – $L \cdot S$ : the complete length dependent factor in the coupling function $T$ .....	24
	Figure 13 – Transfer impedance of typical cables .....	25
	Figure 14 – Magnetic coupling in the braid – Complete flux.....	26
	Figure 15 – Magnetic coupling in the braid – Left-hand lay contribution .....	26
	Figure 16 – Magnetic coupling in the braid – Right-hand lay contribution .....	26
	Figure 17 – Complex plane, $Z_T = \text{Re } Z_T + j \text{Im } Z_T$ , frequency $f$ as parameter.....	27
	Figure 18 – Magnitude (amplitude), $ Z_T(f) $ .....	27

Figure 19 – Typical $Z_T$ (time) step response of an overbraided and underbraided single braided outer conductor of a coaxial cable .....	28
Figure 20 – $Z_T$ equivalent circuits of a braided wire screen .....	29
Figure 21 – Comparison of signal levels in a generic test setup .....	32
Figure 22 – Triaxial set-up for the measurement of the transfer impedance $Z_T$ .....	36
Figure 23 – Equivalent circuit of the triaxial set-up .....	37
Figure 24 – Simulation of the frequency response for $g$ .....	41
Figure 25 – Simulation of the frequency response for $g$ .....	41
Figure 26 – Simulation of the frequency response for $g$ .....	42
Figure 27 – Simulation of the frequency response for $g$ .....	42
Figure 28 – Simulation of the 3 dB cut off wavelength ( $L/\lambda_1$ ) .....	43
Figure 29 – Interpolation of the simulated 3 dB cut off wavelength ( $L/\lambda_1$ ) .....	43
Figure 30 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable) .....	44
Figure 31 – Measurement result of the normalised voltage drop of a single braid screen on a solid PE dielectric in the triaxial set-up .....	45
Figure 32 – Measurement result of the normalised voltage drop of a single braid screen on a foam PE dielectric in the triaxial set-up .....	46
Figure 33 – Triaxial set-up (measuring tube), double short circuited method .....	47
Figure 34 – Simulation of the frequency response for $g$ of a cable having solid PE dielectric ( $\epsilon_{r1}=2,3$ ) .....	48
Figure 35 – Simulation of the frequency response for $g$ of a cable having foamed PE dielectric ( $\epsilon_{r1}=1,6$ ) .....	48
Figure 36 – Simulation of the frequency response for $g$ of a cable having foamed PE dielectric ( $\epsilon_{r1}=1,3$ ) .....	49
Figure 37 – Simulation of the frequency response for $g$ of a cable having PVC dielectric ( $\epsilon_{r1}=5$ ) .....	49
Figure 38 – Interpolation of the simulated 3 dB cut off wavelength ( $L/\lambda_1$ ) .....	50
Figure 39 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable) .....	51
Figure 40 – Simulation of the frequency response for $g$ .....	52
Figure 41 – Interpolation of the simulated 3 dB cut off wavelength ( $L/\lambda_1$ ) .....	53
Figure 42 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable) .....	53
Figure 43 – Definition of transfer impedance .....	55
Figure 44 – Definition of coupling admittance .....	55
Figure 45 – Triaxial measuring set-up for screening attenuation .....	56
Figure 46 – Equivalent circuit of the triaxial measuring set-up .....	56
Figure 47 – Calculated voltage ratio for a typical braided cable screen .....	58
Figure 48 – Calculated periodic functions for $\epsilon_{r1} = 2,3$ and $\epsilon_{r2} = 1,1$ .....	59
Figure 49 – Calculated voltage ratio-typical braided cable screen .....	59
Figure 50 – Equivalent circuit for an electrical short part of the length $\Delta l$ and negligible capacitive coupling .....	61
Figure 51 – $a_s$ of single braid screen, cable type RG 58, $L = 2$ m .....	63
Figure 52 – $a_s$ of single braid screen, cable type RG 58, $L = 0,5$ m .....	64
Figure 53 – $a_s$ of cable type HF 75 0,7/4,8 2YCY (solid PE dielectric) .....	64

Figure 54 – $a_s$ of cable type HF 75 1,0/4,8 02YCY (foam PE dielectric) .....	65
Figure 55 – $a_s$ of double braid screen, cable type RG 223 .....	65
Figure 56 – Schematic for the measurement of the screening attenuation $a_s$ .....	67
Figure 57 – Short circuit between tube and cable screen of the CUT .....	67
Figure 58 – Triaxial set-up, impedance mismatches .....	68
Figure 59 – Calculated voltage ratio including multiple reflections caused by the screening case .....	69
Figure 60 – Calculated voltage ratio including multiple reflections caused by the screening case .....	69
Figure 61 – Attenuation and return loss of a self-made 50 $\Omega$ to 5 $\Omega$ impedance matching adapter .....	70
Figure 62 – equivalent circuit of a load resistance connected to a source .....	71
Figure 63 – Cross-sectional sketch of a typical feed-through configuration .....	72
Figure 64 – Cross-sectional sketch of the test fixture with a feed-through connector (a) and EMI gasket (b) under test .....	73
Figure 65 – Equivalent circuit of the test fixture .....	74
Figure 66 – Two-port network .....	74
Figure 67 – TDR measurement of the test-fixture with inserted “Teflon-through” sample .....	76
Figure 68 – TDR step response from A (Input)-port of test fixture with inserted “Teflon-through” sample .....	77
Figure 69 – TDR step response from B (Output)-port of test fixture with inserted “Teflon-through” sample .....	77
Figure 70 – S-parameter measurement (linear sweep): “Teflon-through” sample .....	78
Figure 71 – S-parameter measurement (logarithmic sweep): “Teflon-through” sample .....	78
Figure 72 – S parameter test setup .....	79
Figure 73 – TDR test setup .....	79
Figure 74 – Test fixture assembled .....	79
Figure 75 – Detailed views of the contact area the test fixture and the secondary side of side opened .....	80
Figure 76 – $S_{21}$ measurements .....	80
Figure 77 – $S_{21}$ measurements of “Teflon-through” and “Sonnenscheibe” feed-through .....	81
Figure 78 – Transfer impedance $Z_T$ of a “Sonnenscheibe” feed-through based on the $S_{21}$ measurement in Figure 77 .....	81
Figure 79 – measurements of a conducting plastic gasket .....	82
Figure 80 – $Z_T$ of the conducting plastic gasket based on the $S_{21}$ measurement in Figure 79 .....	82
Figure 81 – equivalent circuit of the set-up without DUT .....	82
Figure 82 – equivalent circuit of the set-up with inserted DUT .....	83
Figure 83 – Definition of $Z_T$ .....	84
Figure 84 – Calculated coupling transfer function .....	85
Figure 85 – Principle test set-up for measuring the screening attenuation of a connector with the tube in tube procedure .....	86
Figure 86 – Principle test set-up for measuring the coupling attenuation of screened balanced or multipin connectors .....	87
Figure 87 – Principle preparation of balanced or multiconductor connectors for coupling attenuation .....	87

Figure 88 – Comparison of simulation and measurement, linear frequency scale .....	88
Figure 89 – Comparison of simulation and measurement, logarithmic frequency scale .....	89
Figure 90 – Measurement of the coupling attenuation of a CAT6 connector .....	89
Figure 91 – Contact resistances of the test set-up .....	90
Figure 92 – Equivalent circuit of the test set-up with contact resistances .....	90
Table 1 – The coupling transfer function $T$ (coupling function) <sup>a</sup> .....	18
Table 2 – Screening effectiveness of cable test methods for surface transfer impedance $Z_T$ .....	34
Table 3 – Load conditions of the different set-ups .....	38
Table 4 – Parameters of the different set-ups .....	40
Table 5 – Cut-off frequency length product .....	44
Table 6 – Typical values for the factor $\nu$ , for an inner tube diameter of 40 mm and a generator output impedance of 50 $\Omega$ .....	47
Table 7 – Cut-off frequency length product .....	50
Table 8 – Material combinations and the factor $n$ .....	52
Table 9 – Cut-off frequency length product .....	53
Table 10 – Cut-off frequency length product for some typical cables in the different set-ups .....	54
Table 11 – $\Delta a$ in dB for typical cable dielectrics .....	63
Table 12 – Comparison of results of some coaxial cables .....	66
Table 13 – Cable parameters used for simulation .....	88

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

### METALLIC COMMUNICATION CABLE TEST METHODS –

#### **Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic 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 itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 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. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

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

This first edition of technical specification IEC/TS 62153-4-1 cancels and replaces the second edition of the technical report IEC/TR 62153-4-1 published in 2010. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to IEC/TR 62153-4-1:

- a) comparison of the frequency response of different triaxial test set-ups to measure the transfer impedance of cable screens;
- b) background of the shielded screening attenuation test method (IEC 62153-4-4);
- c) background of the shielded screening attenuation test method for measuring the screening effectiveness of feed-throughs and electromagnetic gaskets (IEC 62153-4-10);
- d) background of the shielded screening attenuation test method for measuring the screening effectiveness of RF connectors and assemblies (IEC 62153-4-7).

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

Enquiry draft	Report on voting
46/465/DTS	46/492/RVC

Full information on the voting for the approval of this technical specification 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.

A list of all parts of the IEC 62153 series, under the general title: *Metallic communication cable test methods*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

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

#### 1 Scope

This part of IEC 62153 deals with screening measurements. Screening (or shielding) 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. This technical specification gives a brief introduction to basic concepts and terms trying to reveal the common features of apparently different test methods. It is intended to assist in correct interpretation of test data, and in the better understanding of screening (or shielding) and related specifications and standards.

#### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60096-1:1986, *Radio-frequency cables – Part 1: General requirements and measuring methods*<sup>1</sup>

IEC 60096-4-1, *Radio-frequency cables – Part 4: Specification for superscreened cables – Section 1: General requirements and test methods*<sup>1</sup>

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

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

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

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

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) - Shielded screening attenuation, test method for measuring of the screening attenuation as up to and above 3 GHz*

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

---

<sup>1</sup> This publication has been withdrawn.

IEC 62153-4-6, *Metallic communication cable test methods - Part 4-6: Electromagnetic compatibility (EMC) - Surface transfer impedance - Line injection method*

IEC 62153-4-7, *Metallic communication cable 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 62153-4-10, *Metallic communication cable test methods - Part 4-10: Electromagnetic compatibility (EMC) - Shielded screening attenuation test method for measuring the screening effectiveness of feed-throughs and electromagnetic gaskets double coaxial method*

IEC/TR 62152:2009, *Transmission properties of cascaded two-ports or quadripols – Background of terms and definitions*

EN 50289-1-6: 2002, *Communication cables – Specifications for test methods Part 1-6: Electrical test methods – Electromagnetic performance*

CISPR 25, *Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers*