

TECHNICAL SPECIFICATION



CONSOLIDATED VERSION

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.100.10

ISBN 978-2-8322-8341-7

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

REDLINE VERSION



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

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	15
5.4 Injecting with arbitrary cross-sections	17
5.5 Reciprocity and symmetry	17
5.6 Arbitrary load conditions	17
6 Long cables – coupled transmission lines	17
7 Transfer impedance of a braided wire outer conductor or screen	25
8 Test possibilities	31
8.1 General	31
8.2 Measuring the transfer impedance of coaxial cables	31
8.3 Measuring the transfer impedance of cable assemblies	32
8.4 Measuring the transfer impedance of connectors	32
8.5 Calculated maximum screening level	32
9 Comparison of the frequency response of different triaxial test set-ups to measure the transfer impedance of cable screens	37
9.1 General	37
9.2 Physical basics	37
9.2.1 Triaxial set-up	37
9.2.2 Coupling equations	39
9.3 Simulations	41
9.3.1 General	41
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)	41
9.3.3 Simulation of the double short circuited methods	47
9.4 Conclusion	55
10 Background of the shielded screening attenuation test method (IEC 62153-4-4)	55
10.1 General	55
10.2 Objectives	56
10.3 Theory of the triaxial measuring method	56
10.4 Screening attenuation	61
10.5 Normalised screening attenuation	63
10.6 Measured results	64
10.7 Comparison with absorbing clamp method	66
10.8 Practical design of the test set-up	67
10.9 Influence of mismatches	68
10.9.1 Mismatch in the outer circuit	68
10.9.2 Mismatch in the inner circuit	70

11	Background of the shielded screening attenuation test method for measuring the screening effectiveness of feed-throughs and electromagnetic gaskets (IEC 62153-4-10).....	73
11.1	General.....	73
11.2	Theoretical background of the test Fixtures and their equivalent circuit.....	74
11.3	Pictures and measurement results	77
11.3.1	Characteristic impedance uniformity	77
11.3.2	Measurements of shielding effectiveness.....	79
11.3.3	Calculation of transfer impedance.....	81
11.4	Calculation of screening attenuation for feed-through when the transfer impedance Z_T is known	83
12	Background of the shielded screening attenuation test method for measuring the screening effectiveness of RF connectors and assemblies (IEC 62153-4-7).....	84
12.1	Physical basics	84
12.1.1	Surface transfer impedance Z_T	84
12.1.2	Screening attenuation a_S	85
12.1.3	Coupling attenuation a_C	85
12.1.4	Coupling transfer function.....	85
12.1.5	Relationship between length and screening measurements	86
12.2	Tube in tube set-up (IEC 62153-4-7)	87
12.2.1	General	87
12.2.2	Procedure.....	87
12.2.3	Measurements and simulations.....	89
12.2.4	Influence of contact resistances.....	90
Annex A (normative) Mixed mode S-parameter		92
A.1	General.....	92
A.2	Definition of mixed mode S-parameters.....	92
A.3	Mixed mode S-parameter nomenclature	93
A.4	Termination.....	95
A.5	Reference impedance of a VNA	96
A.6	TP-connecting unit	96
Annex B (informative) Example derivation of mixed mode parameters using the modal decomposition technique		98
Bibliography.....		102

Figure 1	Total electromagnetic field $(\vec{E}_t, \vec{H}_t)$	13
Figure 2	Defining and measuring screening parameters – A triaxial set-up.....	14
Figure 3	Equivalent circuit for the testing of Z_T	16
Figure 4	Equivalent circuit for the testing of $Y_C = j \omega C_T$	16
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	21
Figure 7	Transfer impedance of a typical single braid screen	21
Figure 8	The effect of the summing function on the coupling transfer function of a typical single braid screen cable	22
Figure 9	Calculated coupling transfer functions T_n and T_f for a single braid – $Z_F = 0$	22
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.....	23

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.....	24
Figure 12 – $L \cdot S$: the complete length dependent factor in the coupling function T	25
Figure 13 – Transfer impedance of typical cables	26
Figure 14 – Magnetic coupling in the braid – Complete flux.....	27
Figure 15 – Magnetic coupling in the braid – Left-hand lay contribution	27
Figure 16 – Magnetic coupling in the braid – Right-hand lay contribution	27
Figure 17 – Complex plane, $Z_T = \text{Re } Z_T + j \text{Im } Z_T$, frequency f as parameter.....	28
Figure 18 – Magnitude (amplitude), $ Z_T(f) $	28
Figure 19 – Typical Z_T (time) step response of an overbraided and underbraided single braided outer conductor of a coaxial cable	29
Figure 20 – Z_T equivalent circuits of a braided wire screen.....	30
Figure 21 – Comparison of signal levels in a generic test setup	33
Figure 22 – Triaxial set-up for the measurement of the transfer impedance Z_T	37
Figure 23 – Equivalent circuit of the triaxial set-up.....	38
Figure 24 – Simulation of the frequency response for g	42
Figure 25 – Simulation of the frequency response for g	42
Figure 26 – Simulation of the frequency response for g	43
Figure 27 – Simulation of the frequency response for g	43
Figure 28 – Simulation of the 3 dB cut off wavelength (L/λ_1).....	44
Figure 29 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	44
Figure 30 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	45
Figure 31 – Measurement result of the normalised voltage drop of a single braid screen on a solid PE dielectric in the triaxial set-up	46
Figure 32 – Measurement result of the normalised voltage drop of a single braid screen on a foam PE dielectric in the triaxial set-up.....	47
Figure 33 – Triaxial set-up (measuring tube), double short circuited method	48
Figure 34 – Simulation of the frequency response for g of a cable having solid PE dielectric ($\epsilon_{r1}=2,3$)	49
Figure 35 – Simulation of the frequency response for g of a cable having foamed PE dielectric ($\epsilon_{r1}=1,6$)	49
Figure 36 – Simulation of the frequency response for g of a cable having foamed PE dielectric ($\epsilon_{r1}=1,3$)	50
Figure 37 – Simulation of the frequency response for g of a cable having PVC dielectric ($\epsilon_{r1}=5$).....	50
Figure 38 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	51
Figure 39 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	52
Figure 40 – Simulation of the frequency response for g	53
Figure 41 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	54
Figure 42 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	54
Figure 43 – Definition of transfer impedance.....	56
Figure 44 – Definition of coupling admittance.....	56
Figure 45 – Triaxial measuring set-up for screening attenuation	57

Figure 46 – Equivalent circuit of the triaxial measuring set-up.....	57
Figure 47 – Calculated voltage ratio for a typical braided cable screen	59
Figure 48 – Calculated periodic functions for $\varepsilon_{r1} = 2,3$ and $\varepsilon_{r2} = 1,1$	60
Figure 49 – Calculated voltage ratio-typical braided cable screen	60
Figure 50 – Equivalent circuit for an electrical short part of the length Δl and negligible capacitive coupling	62
Figure 51 – a_s of single braid screen, cable type RG 58, $L = 2$ m.....	64
Figure 52 – a_s of single braid screen, cable type RG 58, $L = 0,5$ m.....	65
Figure 53 – a_s of cable type HF 75 0,7/4,8 2YCY (solid PE dielectric).....	65
Figure 54 – a_s of cable type HF 75 1,0/4,8 02YCY (foam PE dielectric)	66
Figure 55 – a_s of double braid screen, cable type RG 223	66
Figure 56 – Schematic for the measurement of the screening attenuation a_s	68
Figure 57 – Short circuit between tube and cable screen of the CUT	68
Figure 58 – Triaxial set-up, impedance mismatches.....	69
Figure 59 – Calculated voltage ratio including multiple reflections caused by the screening case	70
Figure 60 – Calculated voltage ratio including multiple reflections caused by the screening case	70
Figure 61 – Attenuation and return loss of a self-made $50\ \Omega$ to $5\ \Omega$ impedance matching adapter	71
Figure 62 – equivalent circuit of a load resistance connected to a source	72
Figure 63 – Cross-sectional sketch of a typical feed-through configuration	73
Figure 64 – Cross-sectional sketch of the test fixture with a feed-through connector (a) and EMI gasket (b) under test.....	74
Figure 65 – Equivalent circuit of the test fixture	75
Figure 66 – Two-port network.....	75
Figure 67 – TDR measurement of the test-fixture with inserted “Teflon-through” sample	77
Figure 68 – TDR step response from A (Input)-port of test fixture with inserted “Teflon-through” sample.....	78
Figure 69 – TDR step response from B (Output)-port of test fixture with inserted “Teflon-through” sample.....	78
Figure 70 – S-parameter measurement (linear sweep): “Teflon-through” sample.....	79
Figure 71 – S-parameter measurement (logarithmic sweep): “Teflon-through” sample	79
Figure 72 – S parameter test setup	80
Figure 73 – TDR test setup	80
Figure 74 – Test fixture assembled	80
Figure 75 – Detailed views of the contact area the test fixture and the secondary side of side opened	81
Figure 76 – S_{21} measurements	81
Figure 77 – S_{21} measurements of “Teflon-through” and “Sonnenscheibe” feed-through.....	82
Figure 78 – Transfer impedance Z_T of a “Sonnenscheibe” feed-through based on the S_{21} measurement in Figure 77	82
Figure 79 – measurements of a conducting plastic gasket.....	83
Figure 80 – Z_T of the conducting plastic gasket based on the S_{21} measurement in Figure 79	83
Figure 81 – equivalent circuit of the set-up without DUT	83

Figure 82 – equivalent circuit of the set-up with inserted DUT	84
Figure 83 – Definition of Z_T	85
Figure 84 – Calculated coupling transfer function.....	86
Figure 85 – Principle test set-up for measuring the screening attenuation of a connector with the tube in tube procedure.....	87
Figure 86 – Principle test set-up for measuring the coupling attenuation of screened balanced or multipin connectors.....	88
Figure 87 – Principle preparation of balanced or multiconductor connectors for coupling attenuation.....	88
Figure 88 – Comparison of simulation and measurement, linear frequency scale	89
Figure 89 – Comparison of simulation and measurement, logarithmic frequency scale	90
Figure 90 – Measurement of the coupling attenuation of a CAT6 connector	90
Figure 91 – Contact resistances of the test set-up	91
Figure 92 – Equivalent circuit of the test set-up with contact resistances	91
Figure A.1 – Common two-port network	92
Figure A.2 – Common four port network.....	92
Figure A.3 – Physical and logical ports of a VNA	93
Figure A.4 – Nomenclature of mixed mode S-parameters.....	93
Figure A.5 – Balunless measuring of coupling attenuation, principle set-up with multiport VNA and standard head	94
Figure A.6 – Termination network	95
Figure A.7 – Termination of a screened symmetrical cable, principle	96
Figure B.1 – Voltage and current on balanced cable or cabling under test (CUT)	98
Figure B.2 – Voltage and current on unbalanced DUT	100
Table 1 – The coupling transfer function T (coupling function) ^a	19
Table 2 – Screening effectiveness of cable test methods for surface transfer impedance Z_T	35
Table 3 – Load conditions of the different set-ups	39
Table 4 – Parameters of the different set-ups	41
Table 5 – Cut-off frequency length product	45
Table 6 – Typical values for the factor ν , for an inner tube diameter of 40 mm and a generator output impedance of 50 Ω	48
Table 7 – Cut-off frequency length product	51
Table 8 – Material combinations and the factor n	53
Table 9 – Cut-off frequency length product	54
Table 10 – Cut-off frequency length product for some typical cables in the different set-ups	55
Table 11 – Δa in dB for typical cable dielectrics	64
Table 12 – Comparison of results of some coaxial cables	67
Table 13 – Cable parameters used for simulation	89
Table A.1 – Measurement configurations unbalanced – balanced	94
Table A.2 – Measurement configurations balanced – balanced	95
Table A.3 – TP-connecting unit performance requirements (100 kHz to 2 GHz).....	97

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.

This consolidated version of the official IEC Standard and its amendment(s) has been prepared for user convenience. The IEC Central Office guarantees accuracy of its technical content.

IEC TS 62153-4-1 edition 1.1 contains the first edition (2014-01) [documents 46/465/DTS and 46/492/RVC] and its amendment 1 (2020-05) [documents 46/726/DTS and 46/748/RVDTS].

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

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 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).

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 the base publication and its amendment 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

- 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 4-1: 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*¹

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

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*

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

FINAL VERSION



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

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	15
5.4 Injecting with arbitrary cross-sections	17
5.5 Reciprocity and symmetry	17
5.6 Arbitrary load conditions	17
6 Long cables – coupled transmission lines	17
7 Transfer impedance of a braided wire outer conductor or screen	25
8 Test possibilities	31
8.1 General	31
8.2 Measuring the transfer impedance of coaxial cables	31
8.3 Measuring the transfer impedance of cable assemblies	32
8.4 Measuring the transfer impedance of connectors	32
8.5 Calculated maximum screening level	32
9 Comparison of the frequency response of different triaxial test set-ups to measure the transfer impedance of cable screens	37
9.1 General	37
9.2 Physical basics	37
9.2.1 Triaxial set-up	37
9.2.2 Coupling equations	39
9.3 Simulations	41
9.3.1 General	41
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)	41
9.3.3 Simulation of the double short circuited methods	47
9.4 Conclusion	55
10 Background of the shielded screening attenuation test method (IEC 62153-4-4)	55
10.1 General	55
10.2 Objectives	56
10.3 Theory of the triaxial measuring method	56
10.4 Screening attenuation	61
10.5 Normalised screening attenuation	63
10.6 Measured results	64
10.7 Comparison with absorbing clamp method	66
10.8 Practical design of the test set-up	67
10.9 Influence of mismatches	68
10.9.1 Mismatch in the outer circuit	68
10.9.2 Mismatch in the inner circuit	70

11	Background of the shielded screening attenuation test method for measuring the screening effectiveness of feed-throughs and electromagnetic gaskets (IEC 62153-4-10).....	73
11.1	General.....	73
11.2	Theoretical background of the test Fixtures and their equivalent circuit.....	74
11.3	Pictures and measurement results	77
11.3.1	Characteristic impedance uniformity	77
11.3.2	Measurements of shielding effectiveness.....	79
11.3.3	Calculation of transfer impedance.....	81
11.4	Calculation of screening attenuation for feed-through when the transfer impedance Z_T is known	83
12	Background of the shielded screening attenuation test method for measuring the screening effectiveness of RF connectors and assemblies (IEC 62153-4-7).....	84
12.1	Physical basics	84
12.1.1	Surface transfer impedance Z_T	84
12.1.2	Screening attenuation a_S	85
12.1.3	Coupling attenuation a_C	85
12.1.4	Coupling transfer function.....	85
12.1.5	Relationship between length and screening measurements	86
12.2	Tube in tube set-up (IEC 62153-4-7)	87
12.2.1	General	87
12.2.2	Procedure.....	87
12.2.3	Measurements and simulations.....	89
12.2.4	Influence of contact resistances.....	90
Annex A (normative)	Mixed mode S-parameter	92
A.1	General.....	92
A.2	Definition of mixed mode S-parameters.....	92
A.3	Mixed mode S-parameter nomenclature	93
A.4	Termination.....	95
A.5	Reference impedance of a VNA	96
A.6	TP-connecting unit	96
Annex B (informative)	Example derivation of mixed mode parameters using the modal decomposition technique	98
Bibliography		102

Figure 1	– Total electromagnetic field $(\vec{E}_t, \vec{H}_t)$	13
Figure 2	– Defining and measuring screening parameters – A triaxial set-up.....	14
Figure 3	– Equivalent circuit for the testing of Z_T	16
Figure 4	– Equivalent circuit for the testing of $Y_C = j \omega C_T$	16
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	21
Figure 7	– Transfer impedance of a typical single braid screen	21
Figure 8	– The effect of the summing function on the coupling transfer function of a typical single braid screen cable	22
Figure 9	– Calculated coupling transfer functions T_n and T_f for a single braid – $Z_F = 0$	22
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.....	23

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.....	24
Figure 12 – $L \cdot S$: the complete length dependent factor in the coupling function T	25
Figure 13 – Transfer impedance of typical cables	26
Figure 14 – Magnetic coupling in the braid – Complete flux.....	27
Figure 15 – Magnetic coupling in the braid – Left-hand lay contribution	27
Figure 16 – Magnetic coupling in the braid – Right-hand lay contribution	27
Figure 17 – Complex plane, $Z_T = \text{Re } Z_T + j \text{Im } Z_T$, frequency f as parameter.....	28
Figure 18 – Magnitude (amplitude), $ Z_T(f) $	28
Figure 19 – Typical Z_T (time) step response of an overbraided and underbraided single braided outer conductor of a coaxial cable	29
Figure 20 – Z_T equivalent circuits of a braided wire screen.....	30
Figure 21 – Comparison of signal levels in a generic test setup	33
Figure 22 – Triaxial set-up for the measurement of the transfer impedance Z_T	37
Figure 23 – Equivalent circuit of the triaxial set-up.....	38
Figure 24 – Simulation of the frequency response for g	42
Figure 25 – Simulation of the frequency response for g	42
Figure 26 – Simulation of the frequency response for g	43
Figure 27 – Simulation of the frequency response for g	43
Figure 28 – Simulation of the 3 dB cut off wavelength (L/λ_1).....	44
Figure 29 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	44
Figure 30 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	45
Figure 31 – Measurement result of the normalised voltage drop of a single braid screen on a solid PE dielectric in the triaxial set-up	46
Figure 32 – Measurement result of the normalised voltage drop of a single braid screen on a foam PE dielectric in the triaxial set-up.....	47
Figure 33 – Triaxial set-up (measuring tube), double short circuited method	48
Figure 34 – Simulation of the frequency response for g of a cable having solid PE dielectric ($\epsilon_{r1}=2,3$)	49
Figure 35 – Simulation of the frequency response for g of a cable having foamed PE dielectric ($\epsilon_{r1}=1,6$)	49
Figure 36 – Simulation of the frequency response for g of a cable having foamed PE dielectric ($\epsilon_{r1}=1,3$)	50
Figure 37 – Simulation of the frequency response for g of a cable having PVC dielectric ($\epsilon_{r1}=5$).....	50
Figure 38 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	51
Figure 39 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	52
Figure 40 – Simulation of the frequency response for g	53
Figure 41 – Interpolation of the simulated 3 dB cut off wavelength (L/λ_1).....	54
Figure 42 – 3 dB cut-off frequency length product as a function of the dielectric permittivity of the inner circuit (cable)	54
Figure 43 – Definition of transfer impedance.....	56
Figure 44 – Definition of coupling admittance.....	56
Figure 45 – Triaxial measuring set-up for screening attenuation	57

Figure 46 – Equivalent circuit of the triaxial measuring set-up.....	57
Figure 47 – Calculated voltage ratio for a typical braided cable screen	59
Figure 48 – Calculated periodic functions for $\varepsilon_{r1} = 2,3$ and $\varepsilon_{r2} = 1,1$	60
Figure 49 – Calculated voltage ratio-typical braided cable screen	60
Figure 50 – Equivalent circuit for an electrical short part of the length Δl and negligible capacitive coupling	62
Figure 51 – a_s of single braid screen, cable type RG 58, $L = 2$ m.....	64
Figure 52 – a_s of single braid screen, cable type RG 58, $L = 0,5$ m.....	65
Figure 53 – a_s of cable type HF 75 0,7/4,8 2YCY (solid PE dielectric).....	65
Figure 54 – a_s of cable type HF 75 1,0/4,8 02YCY (foam PE dielectric)	66
Figure 55 – a_s of double braid screen, cable type RG 223	66
Figure 56 – Schematic for the measurement of the screening attenuation a_s	68
Figure 57 – Short circuit between tube and cable screen of the CUT	68
Figure 58 – Triaxial set-up, impedance mismatches	69
Figure 59 – Calculated voltage ratio including multiple reflections caused by the screening case	70
Figure 60 – Calculated voltage ratio including multiple reflections caused by the screening case	70
Figure 61 – Attenuation and return loss of a self-made $50\ \Omega$ to $5\ \Omega$ impedance matching adapter	71
Figure 62 – equivalent circuit of a load resistance connected to a source	72
Figure 63 – Cross-sectional sketch of a typical feed-through configuration	73
Figure 64 – Cross-sectional sketch of the test fixture with a feed-through connector (a) and EMI gasket (b) under test.....	74
Figure 65 – Equivalent circuit of the test fixture	75
Figure 66 – Two-port network.....	75
Figure 67 – TDR measurement of the test-fixture with inserted “Teflon-through” sample	77
Figure 68 – TDR step response from A (Input)-port of test fixture with inserted “Teflon-through” sample.....	78
Figure 69 – TDR step response from B (Output)-port of test fixture with inserted “Teflon-through” sample.....	78
Figure 70 – S-parameter measurement (linear sweep): “Teflon-through” sample	79
Figure 71 – S-parameter measurement (logarithmic sweep): “Teflon-through” sample	79
Figure 72 – S parameter test setup	80
Figure 73 – TDR test setup	80
Figure 74 – Test fixture assembled	80
Figure 75 – Detailed views of the contact area the test fixture and the secondary side of side opened	81
Figure 76 – S_{21} measurements	81
Figure 77 – S_{21} measurements of “Teflon-through” and “Sonnenscheibe” feed-through.....	82
Figure 78 – Transfer impedance Z_T of a “Sonnenscheibe” feed-through based on the S_{21} measurement in Figure 77	82
Figure 79 – measurements of a conducting plastic gasket.....	83
Figure 80 – Z_T of the conducting plastic gasket based on the S_{21} measurement in Figure 79	83
Figure 81 – equivalent circuit of the set-up without DUT	83

Figure 82 – equivalent circuit of the set-up with inserted DUT	84
Figure 83 – Definition of Z_T	85
Figure 84 – Calculated coupling transfer function.....	86
Figure 85 – Principle test set-up for measuring the screening attenuation of a connector with the tube in tube procedure.....	87
Figure 86 – Principle test set-up for measuring the coupling attenuation of screened balanced or multipin connectors.....	88
Figure 87 – Principle preparation of balanced or multiconductor connectors for coupling attenuation.....	88
Figure 88 – Comparison of simulation and measurement, linear frequency scale	89
Figure 89 – Comparison of simulation and measurement, logarithmic frequency scale	90
Figure 90 – Measurement of the coupling attenuation of a CAT6 connector	90
Figure 91 – Contact resistances of the test set-up	91
Figure 92 – Equivalent circuit of the test set-up with contact resistances	91
Figure A.1 – Common two-port network	92
Figure A.2 – Common four port network.....	92
Figure A.3 – Physical and logical ports of a VNA	93
Figure A.4 – Nomenclature of mixed mode S-parameters.....	93
Figure A.5 – Balunless measuring of coupling attenuation, principle set-up with multiport VNA and standard head	94
Figure A.6 – Termination network	95
Figure A.7 – Termination of a screened symmetrical cable, principle	96
Figure B.1 – Voltage and current on balanced cable or cabling under test (CUT)	98
Figure B.2 – Voltage and current on unbalanced DUT	100
Table 1 – The coupling transfer function T (coupling function) ^a	19
Table 2 – Screening effectiveness of cable test methods for surface transfer impedance Z_T	35
Table 3 – Load conditions of the different set-ups	39
Table 4 – Parameters of the different set-ups	41
Table 5 – Cut-off frequency length product	45
Table 6 – Typical values for the factor ν , for an inner tube diameter of 40 mm and a generator output impedance of 50 Ω	48
Table 7 – Cut-off frequency length product	51
Table 8 – Material combinations and the factor n	53
Table 9 – Cut-off frequency length product	54
Table 10 – Cut-off frequency length product for some typical cables in the different set-ups	55
Table 11 – Δa in dB for typical cable dielectrics	64
Table 12 – Comparison of results of some coaxial cables	67
Table 13 – Cable parameters used for simulation	89
Table A.1 – Measurement configurations unbalanced – balanced	94
Table A.2 – Measurement configurations balanced – balanced	95
Table A.3 – TP-connecting unit performance requirements (100 kHz to 2 GHz).....	97

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.

This consolidated version of the official IEC Standard and its amendment(s) has been prepared for user convenience. The IEC Central Office guarantees accuracy of its technical content.

IEC TS 62153-4-1 edition 1.1 contains the first edition (2014-01) [documents 46/465/DTS and 46/492/RVC] and its amendment 1 (2020-05) [documents 46/726/DTS and 46/748/RVDTS].

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

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 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).

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 the base publication and its amendment 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

- 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 4-1: 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*¹

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

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*

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