

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Integrated circuits – EMC evaluation of transceivers –
Part 5: Ethernet transceivers**

**Circuits intégrés – Évaluation de la CEM des émetteurs-récepteurs –
Partie 5: Émetteurs-récepteurs Ethernet**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2021 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.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC online collection - oc.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



IEC 62228-5

Edition 1.0 2021-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Integrated circuits – EMC evaluation of transceivers –
Part 5: Ethernet transceivers**

**Circuits intégrés – Évaluation de la CEM des émetteurs-récepteurs –
Partie 5: Émetteurs-récepteurs Ethernet**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.200

ISBN 978-2-8322-1037-4

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	8
1 Scope.....	10
2 Normative references	10
3 Terms, definitions and abbreviated terms	11
3.1 Terms and definitions.....	11
3.2 Abbreviated terms.....	12
4 General	13
5 Test and operating conditions.....	14
5.1 Supply and ambient conditions.....	14
5.2 Test operation modes	14
5.2.1 General	14
5.2.2 Transceiver configuration for normal operation mode.....	15
5.2.3 Transceiver configuration for low power mode	15
5.3 Definition of BIN.....	15
5.4 Test configuration	16
5.4.1 General configuration for transceiver network	16
5.4.2 General configuration for single transceiver	18
5.4.3 Transceiver network tests – coupling ports and networks for conducted tests	18
5.4.4 Single transceiver tests – coupling ports and networks	21
5.5 Test communication and signals	22
5.5.1 General	22
5.5.2 Test signals for normal operation mode	22
5.5.3 Test signals for low power mode.....	23
5.6 Evaluation criteria	23
5.6.1 General	23
5.6.2 Evaluation criteria for functional operation modes.....	23
5.6.3 Evaluation criteria in unpowered condition after exposure to disturbances	24
5.6.4 Status classes	25
5.7 DUT specific information	26
6 Test and measurement.....	26
6.1 Emission of conducted RF disturbances.....	26
6.1.1 Test method	26
6.1.2 Test setup	26
6.1.3 Test procedure and parameters	27
6.2 Immunity to conducted RF disturbances.....	28
6.2.1 Test method	28
6.2.2 Test setup	28
6.2.3 Test procedure and parameters	29
6.3 Immunity to impulses	33
6.3.1 Test method	33
6.3.2 Test setup	33
6.3.3 Test procedure and parameters	34
6.4 Electrostatic Discharge (ESD).....	36
6.4.1 Test method	36
6.4.2 Test setup	36

6.4.3	Test procedure and parameters	41
7	Test report.....	43
Annex A (normative)	Ethernet test circuits	44
A.1	General.....	44
A.2	Test circuit for Ethernet transceivers for functional tests	44
A.3	Test circuit for Ethernet transceivers for ESD test.....	46
Annex B (normative)	Test circuit boards.....	49
B.1	Test circuit board for transceiver network configuration.....	49
B.2	Test circuit board for single transceiver configuration.....	51
Annex C (informative)	Test of Ethernet transceiver for radiated RF emission and RF immunity	53
C.1	General.....	53
C.2	General configuration for transceiver network	53
C.3	Tests	54
C.3.1	General	54
C.3.2	Emission of radiated RF disturbances.....	58
C.3.3	Immunity to radiated RF disturbances.....	59
Annex D (informative)	Examples for test limits for Ethernet transceiver in automotive application	63
D.1	General.....	63
D.2	Emission of conducted RF disturbances.....	63
D.3	Immunity to conducted RF disturbances.....	64
D.4	Immunity to impulses	68
D.5	Electrostatic discharge (ESD)	68
D.6	Emission of radiated RF disturbances	69
D.7	Immunity to radiated RF disturbances	70
Annex E (informative)	Characterization of common mode chokes for EMC evaluation of Ethernet transceivers	72
E.1	General.....	72
E.2	Test	72
E.2.1	General	72
E.2.2	S-parameter measurement mixed mode.....	73
E.2.3	ESD damage	80
E.2.4	Saturation test at RF disturbances.....	82
E.2.5	Saturation test at ESD	85
E.2.6	TDR measurement of differential mode impedance.....	87
Annex F (informative)	Characterization of ESD suppression devices for EMC evaluation of Ethernet transceivers	89
F.1	General.....	89
F.2	Test	90
F.2.1	General	90
F.2.2	S-parameter measurement mixed mode.....	91
F.2.3	ESD damage	97
F.2.4	ESD discharge current measurement.....	100
F.2.5	Test of unwanted clamping effect at RF immunity tests.....	104
Bibliography.....		108
Figure 1 – Minimum MDI interface test network (Min-BIN).....		16
Figure 2 – Standard MDI interface test network (Std-BIN).....		16

Figure 3 – Optimized MDI interface test network (Opt-BIN)	16
Figure 4 – General test configuration for tests in transceiver network for conducted tests	17
Figure 5 – General test configuration for unpowered ESD test	18
Figure 6 – Transceiver network tests – coupling ports and networks	19
Figure 7 – Coupling ports and networks for unpowered ESD tests	22
Figure 8 – Principle drawing of the maximum deviation on an I-V characteristic	25
Figure 9 – Test setup for measurement of conducted RF disturbances	27
Figure 10 – Test setup for DPI tests	29
Figure 11 – Test setup for impulse immunity tests	33
Figure 12 – Test setup for powered ESD tests – principle arrangement	36
Figure 13 – Test setup for powered ESD tests – stimulation and monitoring	37
Figure 14 – Test setup for unpowered ESD tests – principle arrangement	38
Figure 15 – Test setup for unpowered ESD tests – stimulation and monitoring for function validation pre and post ESD test	40
Figure A.1 – General drawing of the circuit diagram of test network for 100BASE-T1 and 1000BASE-T1 Ethernet transceivers for functional test using conducted test methods	45
Figure A.2 – General drawing of the circuit diagram of test network for 100BASE-TX Ethernet transceivers for functional test using conducted test methods	46
Figure A.3 – General drawing of the circuit diagram for ESD tests of Ethernet transceivers in powered mode	47
Figure A.4 – General drawing of the circuit diagram for ESD tests of Ethernet transceivers in unpowered mode	48
Figure B.1 – Example of functional conducted test board for Ethernet transceiver ICs (100BASE-T1)	49
Figure B.2 – Example of powered ESD test board for Ethernet transceivers ICs (100BASE-T1)	50
Figure B.3 – Example of unpowered ESD test board for Ethernet transceivers ICs (100BASE-T1), top layer	51
Figure B.4 – Example of unpowered ESD test board for Ethernet transceivers ICs (100BASE-T1), bottom layer	51
Figure C.1 – General test configuration for tests in transceiver network used for radiated tests	53
Figure C.2 – General drawing of the circuit diagram of test network for 100BASE-T1 and 1000BASE-T1 Ethernet transceivers for functional test using radiated RF test methods	55
Figure C.3 – Example of functional radiated test board for Ethernet transceiver ICs (100BASE-T1), top layer (DUT side)	56
Figure C.4 – Example of functional radiated test board for Ethernet transceiver ICs (100BASE-T1), bottom layer (external circuitry side)	57
Figure C.5 – Test setup for measurement of radiated RF emission	58
Figure C.6 – Test setup for radiated RF immunity tests	60
Figure D.1 – Example of limits for conducted RF emission – MDI Opt-BIN, V_{BAT} and WAKE	63
Figure D.2 – Example of limits for conducted RF emission – local supplies	64
Figure D.3 – Example of limits for conducted RF immunity for functional status class A _{1C} – MDI Opt-BIN	65

Figure D.4 – Example of limits for conducted RF immunity for functional status class A_{IC} – V_{BAT} and WAKE.....	65
Figure D.5 – Example of limits for conducted RF immunity for functional status class C_{IC} or D_{IC} – MDI Opt-BIN	67
Figure D.6 – Example of limits for conducted RF immunity for functional status class C_{IC} or D_{IC} – V_{BAT} and WAKE	67
Figure D.7 – Example of limits for radiated RF emission for IC stripline with 6,7 mm active conductor height.....	69
Figure D.8 – Example of limits for radiated RF immunity	70
Figure E.1 – General electrical drawing of a CMC	72
Figure E.2 – Test setup for S-parameter measurements at CMC.....	73
Figure E.3 – Example of test board 4-port S-parameter measurement at CMC – mixed mode, top layer.....	74
Figure E.4 – Example of test board 3-port S-parameter measurement at CMC – single ended, top layer.....	74
Figure E.5 – Recommended characteristics for S_{dd11} , S_{dd22} (RL) for CMC.....	77
Figure E.6 – Recommended characteristics for S_{dd21} (IL) for CMC.....	78
Figure E.7 – Recommended characteristics for S_{cc21} (CMR) for CMC	78
Figure E.8 – Recommended characteristics for S_{dc11} , S_{dc22} (LCL) for CMC	79
Figure E.9 – Recommended characteristics for S_{sd21} , S_{sd12} (DCMR) and S_{ds21} , S_{ds12} (CDMR) for CMC	79
Figure E.10 – Test setup for ESD damage tests at CMC	80
Figure E.11 – Example of ESD test board for CMC, top layer.....	81
Figure E.12 – Test setup for RF saturation measurements at CMC	83
Figure E.13 – Example of RF saturation / S-parameter test board for CMC, top layer.....	83
Figure E.14 – Test setup for ESD saturation measurements at CMC.....	85
Figure E.15 – Example of ESD saturation test board for CMC, top layer	85
Figure E.16 – Example of ESD saturation tests results for CMC.....	87
Figure E.17 – Test setup for TDR measurement at CMC.....	87
Figure E.18 – Example of TDR test board for CMC, top layer.....	88
Figure F.1 – Arrangement of ESD suppression device within the 100BASE-T1 and 1000BASE-T1 MDI interface	90
Figure F.2 – Test setup for S-parameter measurements at ESD suppression device.....	91
Figure F.3 – Example of test board 4-port S-parameter measurement for ESD suppression device – mixed mode, top layer.....	92
Figure F.4 – Example of test board 3-port S-parameter measurement for ESD suppression device – single ended, top layer.....	92
Figure F.5 – Recommended characteristics for S_{dd11} (RL) for ESD suppression device	95
Figure F.6 – Recommended characteristics for S_{dd21} (IL) for ESD suppression device.....	95
Figure F.7 – Recommended characteristics for S_{sd21} (DCMR) for ESD suppression device.....	96
Figure F.8 – Test setup for ESD damage tests at ESD suppression device	97
Figure F.9 – Example of ESD test board for ESD suppression device, top layer.....	98
Figure F.10 – Test setup for ESD discharge current measurement at ESD suppression device.....	100

Figure F.11 – Example of ESD discharge current test board for ESD suppression device, top and bottom layer	101
Figure F.12 – Example of test results and recommended limits for remaining ESD discharge current after the MDI test network for ESD suppression device	103
Figure F.13 – Test setup for RF clamping test at ESD suppression device	104
Figure F.14 – Example of test board RF clamping test at suppression device, top layer	105
Figure F.15 – Recommended test power levels for RF clamping tests at ESD suppression device	107
Table 1 – Overview of measurements and tests	13
Table 2 – Supply and ambient conditions for functional operation	14
Table 3 – Definition for transceiver configuration for normal operation mode	15
Table 4 – Definition for transceiver mode configuration for low power mode	15
Table 5 – Selection recommendation of MII interfaces for transceiver network configuration	18
Table 6 – Transceiver network tests – component value definitions of coupling ports and networks	20
Table 7 – Definitions of coupling ports for unpowered ESD tests	22
Table 8 – Definition for transceiver mode configuration for normal operation mode	23
Table 9 – Evaluation criteria for Ethernet transceiver	24
Table 10 – Definition of functional status classes	25
Table 11 – Settings of the conducted RF measurement equipment	27
Table 12 – Conducted emission measurements	28
Table 13 – Specifications for DPI tests	30
Table 14 – DPI tests for functional status class A _{IC} evaluation of Ethernet transceivers	31
Table 15 – DPI tests for functional status class C _{IC} or D _{IC} evaluation of Ethernet transceivers	32
Table 16 – Specifications for impulse immunity tests	34
Table 17 – Parameters for impulse immunity test	34
Table 18 – Impulse immunity tests for functional status class A _{IC} evaluation of Ethernet transceivers	35
Table 19 – Impulse immunity tests for functional status class C _{IC} or D _{IC} evaluation of Ethernet transceivers	35
Table 20 – Specifications for ESD tests	41
Table 21 – ESD tests in powered mode for functional status class A _{IC} , C _{IC} and D _{IC} evaluation of Ethernet transceivers	42
Table 22 – ESD tests in unpowered mode for functional status class D _{IC} evaluation of Ethernet transceiver ICs	43
Table B.1 – Parameter ESD test circuit board	52
Table C.1 – Settings of the radiated RF measurement equipment	59
Table C.2 – Radiated RF emission measurements	59
Table C.3 – Specifications for radiated RF immunity tests	61
Table C.4 – Radiated RF immunity tests for functional status class A _{IC} evaluation of Ethernet transceivers	62
Table D.1 – Example of limits for conducted RF emission – test cases with recommended limit classes	64

Table D.2 – Example of limits for conducted RF immunity – test cases with recommended limit classes for functional status class A _{IC}	66
Table D.3 – Example of limits for conducted RF immunity – test cases with recommended limit classes for functional status class C _{IC} or D _{IC}	68
Table D.4 – Example of limits for impulse immunity – Class I	68
Table D.5 – Example of limits for impulse immunity – test cases with recommended limit classes for functional status class C _{IC} or D _{IC}	68
Table D.6 – Example of limits for powered and unpowered ESD tests – test cases with recommended limits for functional status class A1 _{IC} , A2 _{IC} , A3 _{IC} , C _{IC} or D _{IC}	69
Table D.7 – Example of limits for radiated RF emission – test cases with recommended limit classes	70
Table D.8 – Example of limits for radiated RF immunity – test cases with recommended limit classes	71
Table E.1 – Test procedure and parameters for 3-port test board characterization for CMC	75
Table E.2 – Test procedure and parameters for S-parameter measurements at CMC	76
Table E.3 – Required S-parameter measurements for CMC	77
Table E.4 – Test parameters for ESD damage tests at CMC	81
Table E.5 – Required ESD tests for damage for CMC	82
Table E.6 – Test procedure and parameters for RF saturation tests at CMC	84
Table E.7 – Required RF saturation tests for CMC	84
Table E.8 – Test procedure and parameters for ESD saturation tests at CMC	86
Table E.9 – Required ESD saturation tests for CMC	86
Table E.10 – ESD saturation break down voltage classes for CMC	86
Table E.11 – Test procedure and parameters for TDR measurement at CMC	88
Table E.12 – Required TDR measurements for CMC	88
Table F.1 – Specification of ESD suppression device	89
Table F.2 – Test procedure and parameters for 3-port test board characterization for ESD suppression device	93
Table F.3 – Test procedure and parameters for S-parameter measurements at ESD suppression device	94
Table F.4 – Required S-parameter measurements for ESD suppression device	94
Table F.5 – Test parameters for ESD damage tests at ESD suppression device	99
Table F.6 – Required ESD tests for damage for ESD suppression device	99
Table F.7 – Test parameters for ESD discharge current measurement at ESD suppression device	102
Table F.8 – Required current measurement for ESD suppression device	102
Table F.9 – Recommended limits for remaining ESD discharge current after the MDI test network for ESD suppression device	103
Table F.10 – Limit classes and related applied ESD test voltages	104
Table F.11 – Test procedure and parameters for RF clamping tests at ESD suppression device	106
Table F.12 – Required RF clamping tests for ESD suppression device	107

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INTEGRATED CIRCUITS –
EMC EVALUATION OF TRANSCEIVERS –**
Part 5: Ethernet transceivers**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.

International Standard IEC 62228-5 has been prepared by subcommittee 47A: Integrated circuits, of IEC technical committee 47: Semiconductor devices.

The text of this International Standard is based on the following documents:

Draft	Report on voting
47A/1115/FDIS	47A/1117/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document 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.

INTEGRATED CIRCUITS – EMC EVALUATION OF TRANSCEIVERS –

Part 5: Ethernet transceivers

1 Scope

This part of IEC 62228 specifies test and measurement methods for EMC evaluation of Ethernet transceiver ICs under network condition. It defines test configurations, test conditions, test signals, failure criteria, test procedures, test setups and test boards. It is applicable for transceiver of the Ethernet systems

- 100BASE-T1 according to ISO/IEC/IEEE 8802-3/AMD1;
- 100BASE-TX according to ISO/IEC/IEEE 8802-3;
- 1000BASE-T1 according to ISO/IEC/IEEE 8802-3/AMD4

and covers

- the emission of RF disturbances;
- the immunity against RF disturbances;
- the immunity against impulses;
- the immunity against electrostatic discharges (ESD).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61967-1, *Integrated circuits – Measurement of electromagnetic emissions – Part 1: General conditions and definitions*

IEC 61967-4, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 4: Measurement of conducted emissions, 1 ohm/150 ohm direct coupling method*

IEC 62132-1, *Integrated circuits – Measurement of electromagnetic immunity – Part 1: General conditions and definitions*

IEC 62132-4, *Integrated circuits – Measurement of electromagnetic immunity 150 kHz to 1 GHz – Part 4: Direct RF power injection method*

IEC 62215-3, *Integrated circuits – Measurement of impulse immunity – Part 3: Non-synchronous transient injection method*

IEC 62228-1, *Integrated circuits – EMC evaluation of transceivers – Part 1: General conditions and definitions*

ISO 10605, *Road vehicles – Test methods for electrical disturbances from electrostatic discharge*