ISO/IEC TS 11801-9903

Edition 2.0 2025-09

TECHNICAL SPECIFICATION

Information technology - Generic cabling for customer premises - Part 9903: Modelling of channels and links

ICS 35.200

ISBN 978-2-8327-0698-5

ISO/IEC TS 11801-9903: 2025-09(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2025 ISO/IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
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 It also gives information on projects, replaced and withdrawn publications.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 Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. 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 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

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

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms, definitions, symbols and abbreviated terms 7
3.1 Terms and definitions 7
3.2 Symbols and abbreviated terms 8
4 Matrix model 9
4.1 General 9
4.2 Matrix definition 10
4.2.1 General 10
4.2.2 Quadriports 10
4.2.3 Matrix port definition for a two-pair system representative for modelling purposes 10
4.2.4 Operational scattering matrix 10
4.2.5 General naming convention 11
4.2.6 S-matrix 12
4.2.7 Passivity 12
4.2.8 Operational reflection loss matrix 13
4.2.9 Transmission matrix (T-matrix) 13
4.2.10 S-matrix of cabling 13
4.3 General case using mixed-mode matrices 14
4.3.1 General 14
4.3.2 Mixed-mode S-parameters matrix and submatrices 14
Annex A (informative) S to T and T to S-matrix conversion formulas 17
A.1 Overview 17
A.2 Formulas 17
A.2.1 S to T-matrix 17
A.2.2 T to S matrix 17
A.2.3 Conversion matrices 17
Annex B (informative) Transmission model terms and definitions 19
B.1 Comparison of namings 19
B.2 General 20
B.3 Background of terms and definitions 20
B.3.1 Operational attenuation 20
B.3.2 Operational transfer function (T_{B}) 22
B.3.3 Image or wave transfer function (T) 22
B.3.4 Insertion transfer function of a two-port (T_{BI}) 22
B.3.5 Insertion transfer function (T_{BI}) 22
B.3.6 Operational reflection loss transfer function (T_{ref} = S_{ref}) of a junction 22
Annex C (informative) Channel and permanent link models for balanced cabling 24
C.1 General 24
C.2 Insertion loss 24
C.2.1 Insertion loss of the channel configuration 24
C.2.2 Insertion loss of the permanent link configurations 25

C.2.3 Assumptions for insertion loss 25
C.3 NEXT 26
C.3.1 NEXT of the channel configuration 26
C.3.2 NEXT of the permanent link configurations 26
C.3.3 Assumptions for NEXT 27
C.4 ACR-F 30
C.4.1 ACR-F of the channel configuration 30
C.4.2 ACR-F for the permanent link configurations 31
C.4.3 Assumptions for ACR-F 31
C.5 No Return loss 31
C.5.1 Return loss of the channel and permanent link configurations 31
C.5.2 Assumptions for the return loss circuit analysis method 32
C.6 PS ANEXT link modelling 35
C.6.1 General 35
C.6.2 PS ANEXT between connectors 35
C.6.3 PS ANEXT between cable segments 35
C.6.4 Principles of link modelling 36
C.7 PS AACR-F link modelling 36
C.7.1 General 36
C.7.2 PS AFEXT between connectors 36
C.7.3 PS AACR-F between cable segments 36
C.7.4 Principles of link modelling 37
C.7.5 Impact of PS AACR-F in channels and links with substantially different lengths 37
C.8 Component assumptions for modelling purposes 40
Annex D (informative) Alternative calculation of matrix terms for limit lines 42
D.1 General 42
D.2 Extracting limit lines 42
D.3 Formulas to extract the cabling limit lines 43
D.3.1 Operational attenuation 43
D.3.2 Crosstalk 43
D.3.3 Reflection and return loss (RL) 44
D.4 Component values used as input to the model 44
D.4.1 General 44
D.4.2 Cable 45
D.4.3 Connections 47
Annex E (informative) Signal-to-noise ratio modelling 49
E.1 General 49
E.2 Transmission system model 49
E.2.1 General 49
E.2.2 Transmitter pulse 49
E.2.3 Receiving criteria 49
E.2.4 The electrical channel 49
E.2.5 Power spectral density (PSD): 50
E.2.6 Noise definition 50
E.2.7 Modulation 51
E.2.8 Bit error ratio (BER) 52
E.2.9 Signal-to-noise ratio (SNR) 52
E.3 Calculation examples 53

E.3.1 General 53
E.3.2 Comparison with other calculations: 53
Bibliography 56

Figure 1 – Matrix definition of a 4-port two twisted pair system 10
Figure 2 – Operational scattering parameters example from port 2 11
Figure 3 – Transmission matrix concatenation showing an example of a 2-connector permanent link 13
Figure B.1 – Defining the operational attenuation and the operational transfer functions of a two-port 21
Figure B.2 – Defining the reflection transfer functions and the return loss of a junction 23
Figure C.1 – Example of computation of NEXT with higher precision 27
Figure C.2 – Example of increased impact of PS AFEXT 37
Figure D.1 – Graphical example of a NEXT calculation showing statistical results (red dots) and final calculation (blue line) 43
Figure D.2 – 100 m cable return loss without reflection at both ends 47
Figure D.3 – 100 m cable return loss with a reflection of 0,03 at both ends (6 Ω mismatch, ~23 dB return loss at 1 MHz) 47
Figure E.1 – Different noise spectra 51
Figure E.2 – Results using this calculation, which show good agreement with similar calculations in [12] 54
Figure E.3 – Presentation on best modulation scheme (PAM4) and signal-to-noise ratio (SNR) 55

Table 1 – All four ports operational scattering parameter definition 11
Table 2 – TCL/TCTL and LCL/LCTL port designations 11
Table 3 – Equal S-parameters for real components 12
Table 4 – Interrelation of mixed-mode mode-conversion and related parameters 14
Table 5 – Mixed-mode S-parameter notation 15
Table B.1 – Comparison of naming in ISO/IEC 11801-1 and ISO/IEC TS 11801-9903 19
Table C.1 – Insertion loss deviation 25
Table C.2 – Modelling assumptions for cable transmission parameters 40
Table C.3 – Model input assumptions used in the statistical calculation (Class E_A) 41
Table C.4 – Model input assumptions used in the statistical calculation (Class F_A) 41
Table E.1 – Typical noise limits for 1-pair channels 51
Table E.2 – Comparison of different modulation PAM levels 52
Table E.3 – Summary 54

Information technology - Generic cabling for customer premises - Part 9903: Modelling of channels and links

FOREWORD

1) ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.
2) The formal decisions or agreements of IEC and ISO 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 and ISO National bodies.
3) IEC and ISO documents have the form of recommendations for international use and are accepted by IEC and ISO National bodies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC and ISO documents is accurate, IEC and ISO 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 and ISO National bodies undertake to apply IEC and ISO documents transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC and ISO document and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC and ISO do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC and ISO marks of conformity. IEC and ISO are not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this document.
7) No liability shall attach to IEC and ISO or their directors, employees, servants or agents including individual experts and members of its technical committees and IEC and ISO National bodies 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 ISO/IEC document or any other IEC and ISO documents.
8) Attention is drawn to the Normative references cited in this document. Use of the referenced publications is indispensable for the correct application of this document.
9) IEC and ISO draw attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC and ISO take no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC and ISO had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch and www.iso.org/patents. IEC and ISO shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 11801-9903 has been prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2021. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the expansion of the list of specified parameters to include mixed-mode mode-conversion and related unbalance attenuation parameters;
b) the addition of an informative annex covering the topic of signal-to-noise ratio and its relation to the S-parameter matrix channel model.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
JTC1-SC25/3324/DTS	JTC1-SC25/3333/RVDTS

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 Technical Specification is English.

A list of all parts in the ISO/IEC 11801 series, published under the general title *Information technology - Generic cabling for customer premises*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, and the ISO/IEC Directives, JTC 1 Supplement available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

INTRODUCTION

This document includes models and assumptions, which support the limits for the channel and permanent link test configurations in ISO/IEC 11801-1. These are based on the performance requirements of cable and connecting hardware as specified in IEC standards. Modelling of channels and links can be done in different ways.

This document provides models that assure that a channel created by adding compliant patch cords to a permanent link will meet the applicable channel performance limits.

1 Scope

This part of ISO/IEC 11801, which is a Technical Specification, establishes modelling of limits for mixed-mode transmission parameters within and between two pairs of balanced cabling. This document consists of a detailed description of matrix modelling and gives explanations on how to convert matrices, by using the S to T and T to S matrix conversion. Further it consists of terms and definitions used, how specific parameters are modelled, alternative calculation and signal-to-noise ratio (SNR) modelling.

Chain parameters and alternative approaches and formulas are described for combining component cable and connector transmission parameters into cabling link and channel transmission parameters. S-parameter limit matrix formulas are covered, which can be transformed into T-parameter limit matrices for use in chain parameter link and channel limit formulas. The formulas are applicable to all transmission parameters for forming complete differential-mode, mixed-mode, and common-mode link and channel models.

Terms and definitions used for modelling are discussed, together with how modelling is done for specific transmission parameters. Alternative calculation models are explained, and the SNR modelling introduced.

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.

ISO/IEC 11801-1, *Information technology - Generic cabling for customer premises - Part 1: General requirements*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
attenuation
decrease in magnitude of power of a signal that propagates along a single conductor or pair of conductors of a cable

Note 1 to entry: Attenuation is expressed in dB/m; see IEC 61156-1.

3.1.2
connection
mated device or combination of devices including terminations used to connect cables or cable elements to other cables, cable elements or application-specific equipment

EXAMPLE Jack and plug; see ISO/IEC 11801-1.

3.1.3
image attenuation
wave attenuation
attenuation when a two-port is terminated by its input and output characteristic impedances with no reflections at input and output

Note 1 to entry: The wave attenuation of cables is length scalable; see B.3.3.

3.1.4
insertion loss
loss incurred by inserting a device between a source and load of equal impedance

Note 1 to entry: The device itself can have a different impedance from the load and source impedance.

Note 2 to entry: The terms operational attenuation and operational insertion loss are sometimes associated with this definition; see B.3.2.

3.1.5
insertion loss deviation
difference between the measured insertion loss of cascaded components and the insertion loss determined by the sum of the individual component insertion losses

3.1.6
operational attenuation
ratio of the square root of the maximum available power wave vector emitted by the generator and the square root of the power wave vector absorbed by the load of the two-port

Note 1 to entry: The operational attenuation is not length scalable (see also B.3.1 and B.3.2).

Note 2 to entry: The operational attenuation is expressed in decibels (dB) and radians (rad).

3.1.7
unitarity
mathematical concept for matrices to define passivity

Note 1 to entry: Unitarity is a necessary property of the reflection matrix used for the mismatch loss between two cabling segment matrices for the cascaded segment's operational attenuation. This assures linearity or passivity, thus the forward loss and reverse loss are equal at the junction; see 4.2.8

3.1.8
operational reflection
loss due to the reflection at a junction

Note 1 to entry: See also B.3.6.

Note 2 to entry: See also 4.2.8

3.1.9
raised cosine
special pulse and spectra shape suited for baseband data transmission

3.2 Symbols and abbreviated terms

A	operational wave attenuation (Np)
A_T	operational wave transfer function (Np)
AWGN	additive white Gaussian noise
B	operational phase (rad)
B_{RAND}	random phase (rad)
B_T	operational phase transfer function (rad)
BER	bit error ratio

DRL	distributed return loss (dB)
f	frequency (MHz)
FEXT	operational far-end crosstalk loss (dB)
$FEXT_T$	operational FEXT transfer function (dB)
IL	insertion loss (dB)
LCL	operational longitudinal conversion loss (dB)
LCL_T	operational LCL transfer function (dB)
LCTL	operational longitudinal conversion transfer loss (dB)
$LCTL_T$	operational LCTL transfer function (dB)
NEXT	operational near-end crosstalk loss (dB)
$NEXT_T$	operational NEXT transfer function (dB)
PHY	physical layer interface
PSD	power spectrum density
RL	return loss (dB)
SNR	signal-to-noise ratio
TCL	operational transverse conversion loss (dB)
TCL_T	operational TCL transfer function (dB)
TCTL	operational transverse conversion transfer loss (dB)
$TCTL_T$	operational TCTL transfer function (dB)
ρ	(rho) operational reflection transfer function, junction reflection coefficient

4 Matrix model

4.1 General

The model that is used is a concatenated matrix calculation as discussed in IEC TR 62152 [1][1] for a 2-port system. For a 2-pair balanced cabling calculation, a 4-port differential matrix as shown in Figure 1 shall be used.

The model assumes that all components are specified with S-parameters and these parameters are then used to fill an S-matrix for every cabling component.

To concatenate components these S-matrices are transformed into transmission T-matrices, which can then be multiplied in the appropriate order to simulate the transmission characteristics of the concatenated components (for details see IEC TR 62152 [1]). The relation between impedance parameters used in the IEC TR 62152 transmission line model and the S-parameters used in the ISO/IEC 11801-1 [2] channel and permanent link models is covered in Annex B.

To evaluate the transmission performance of the modelled channel or permanent link, the calculated T-matrix of the cabling is transformed back into an S-matrix providing the expected transmission parameters of the cabling system. The relation between S-parameters and T-parameters is covered in Annex A.

[1] Numbers in square brackets refer to the Bibliography.