BS ISO 4426:2021

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Intelligent transport systems — Lower layer protocols for usage in the European digital tachograph

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National foreword

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Intelligent transport systems — Lower layer protocols for usage in the European digital tachograph

Systèmes de transport intelligents - Protocoles de couche basse pour utilisation dans le cadre du chrono tachygraphe numérique européen

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Foreword

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document is designed to encompass communication requirements in support of the Smart Digital Tachograph (SDT) as identified by Regulation 2016/799 of the European Union[23].

This document specifies SDT Communications (SDTC). SDTC is the application of CEN Dedicated Short Range Communication (DSRC) for SDT. See the following:

— EN 12253, *Road transport and traffic telematics — Dedicated short-range communication — Physical layer using microwave at 5,8 GHz*[1]

— EN 12795, *Road transport and traffic telematics — Dedicated Short Range Communication (DSRC) — DSRC data link layer: medium access and logical link control*[2]

— EN 12834, *Road transport and traffic telematics — Dedicated Short Range Communication (DSRC) — DSRC application layer*[3]

— EN 13372, *Road transport and traffic telematics — Dedicated short-range communication — Profiles for RTTT applications*[4]

Complementing the standardized specifications and descriptions, several private documents describe this dedicated short range semi-passive communication technology in an informative manner, providing additional detailed explanations and implementation hints. See for example:

— DSRC tutorial published by ESF GmbH in July 2003 (publicly available)[24];

— GSS industry specification published in August 2003[25] (no longer available from the authors; essential content is now available in ISO 15509);

It is to be noted that the abovementioned private documents provide information that can be essential to easily achieving interoperability with existing DSRC equipment and optimum performance.

EN 12253[1] deals with the physical layer of the DSRC protocol stack presented in Figure 1; i.e. it comprises requirements for Open Systems Interconnection (OSI) Layer 1 at 5,8 GHz for DSRC.

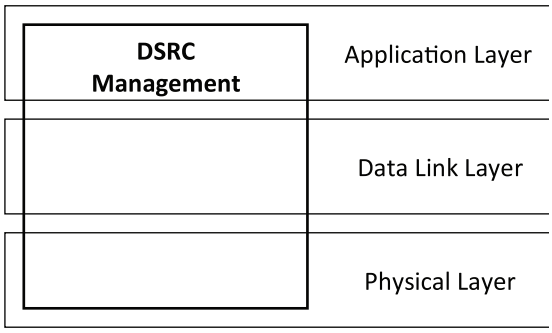

Figure 1 — DSRC protocol stack

EN 12253[1] does not include associated measurement procedures for verification of the requirements. Test methods for conformity are provided in ETSI EN 300674-1[12], ETSI EN 300674-2-1[13] and ETSI EN 300674-2-2[14].

EN 12253[1] caters for on-board units based on transponder technologies. Furthermore, it allows for mixed time, frequency and space division multiple access approaches.

EN 12253[1] is conceived for the 10 MHz part (i.e. 5,795 GHz to 5,805 GHz) of the ISM band at 5,8 GHz which is recommended by ECC/DEC(01)01[10]. An additional sub-band (5,805 GHz - 5,815 GHz) may be

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allocated on a national basis. National restrictions on the usage of these frequency bands can apply according to CEPT/ERC REC 70-03[11].

EN 12795[2] gives the architecture and services offered by the DSRC data link layer.

EN 12834[3] and the almost identical ISO 15628 give the architecture and services offered by the DSRC application layer.

EN 13372[4] deals with the interlayer management of the DSRC protocol stack.

Figure 2 illustrates the global data flow between the elements of the SDTC stack, (physical layer, data link layer and application layer) and the SDT application.

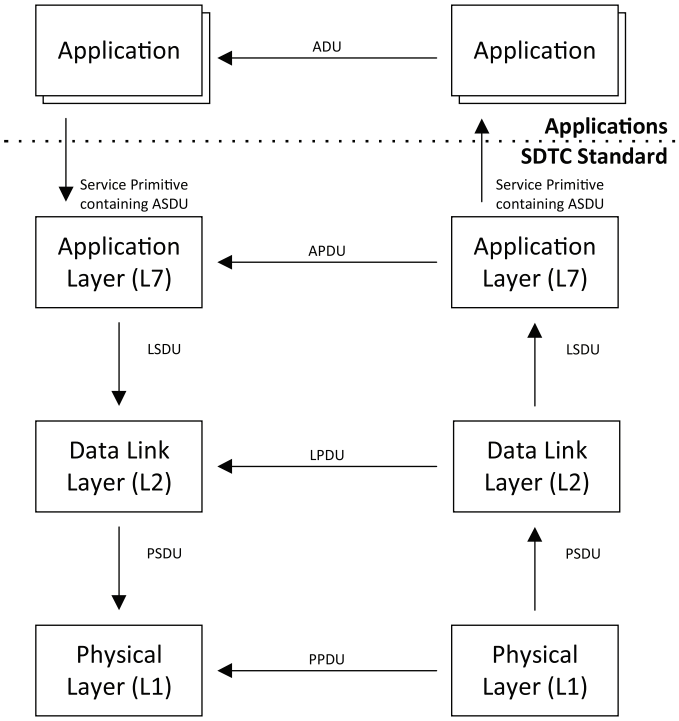

Figure 2 — Architecture and data flow of the SDTC stack

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Intelligent transport systems — Lower layer protocols for usage in the European digital tachograph

1 Scope

This document specifies communication requirements in support of the Smart Digital Tachograph (SDT) as identified by Regulation 2016/799 of the European Union[23].

The specification covers:

— the physical layer at 5,8 GHz for SDT communications (SDTC);

— the data link layer (DLL) of SDTC;

— the application layer of SDTC;

— SDTC profiles which provide coherent sets of communication tools for applications based on SDTC.

This document provides further information beneficial for the design and development of SDTC equipment.

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 15628, *Intelligent transport systems — Dedicated short range communication (DSRC) — DSRC application layer*

ISO/IEC 13239, *Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
adjacent channel
neighbouring SDTC channel for use by two or more emissions

Note 1 to entry: It is possible that a SDTC channel has either one of two adjacent channels.

3.2
antenna bore sight direction
direction of maximum antenna gain

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3.3
application
set of processes including related functions and structured data that uses the services offered by the SDTC communication stack

3.4
beacon service table
BST
data structure transmitted by the fixed equipment indicating available services

3.5
bit error ratio
averaged number of erroneous bits relative to the total number of transmitted bits

3.6
co-channel
refers to the use of the same SDTC channel by two or more emissions

3.7
communication initialization
procedure used to establish communication between an RSU and a newly arrived OBU

Note 1 to entry: Terms prefixed with D present downlink parameters; downlink parameters apply to transmission of data from RSU to OBU.

3.8
D1 — carrier frequencies
number and values of the downlink carrier frequencies, which are equal to the frequencies of the CW, transmitted by the RSU and used by transponder OBUs for uplink communication

Note 1 to entry: Each carrier frequency is the centre frequency of a downlink channel.

3.9
D1a — tolerance of carrier frequencies
maximum deviation of the carrier frequency resulting from any cause

Note 1 to entry: It is expressed in parts per million (ppm)

EXAMPLE ±1 ppm of a 5,8 GHz carrier allows for the carrier frequency to be in the range of 5,8 GHz ± 5,8 kHz.

3.10
D2 — RSU transmitter spectrum mask
maximum allowed power within a defined frequency band emitted by the RSU transmitter

3.11
D3 — OBU minimum frequency range
minimum range of frequencies that has to be received by the OBU receiver

3.12
D4 — maximum E.I.R.P.
maximum allowed value of E.I.R.P.

3.13
D4a — angular E.I.R.P. mask
E.I.R.P. as a function of the angle Θ, where Θ indicates the angle relative to a vector perpendicular to the road surface, pointing downwards

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3.14
D5 — polarization
locus of the tip of the vector of the electrical field strength in a plane perpendicular to the transmission vector

EXAMPLE Horizontal and vertical linear polarization and left- and right-hand circular polarization.

3.15
D5a — cross-polarization
ellipticity of polarization
antenna designed to transmit left-hand circular waves, which can transmit some right-hand circular waves in addition

Note 1 to entry: Cross-polar discrimination (XPD) is defined as the ratio between left- and right-hand circular power, P_{LHC}/P_{RHC}, when the total power transmitted is $P_{LHC} + P_{RHC}$. XPD is related to the ellipticity of polarization.

3.16
D6 — modulation
keying of the carrier wave by coded data

EXAMPLE Amplitude shift keying (ASK), phase shift keying (PSK), frequency shift keying (FSK) and linear amplitude modulation (AM).

3.17
D6a — modulation index
ratio of the variation of the modulation parameter (frequency, amplitude, phase) caused by the modulation signal (data signal)

EXAMPLE Given the minimum and maximum values V_{max} and V_{min} of the envelope amplitude V of the modulated signal, the amplitude modulation index m is defined as:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} .$$

3.18
D7 — data coding
downlink base band signal presentation, i.e. a mapping of logical bits to physical signals

EXAMPLE Bi-phase schemes (Manchester, FM0, FM1, differential Manchester), NRZ and NRZI. NRZI: No transition at beginning of "1" bit, transition at beginning of "0" bit, no transition within bit.

3.19
D8 — bit rate
number of bits per second, independent of the data coding

3.20
D8a — tolerance of bit clock
maximum downlink deviation of the bit clock resulting from any cause, expressed in ppm

EXAMPLE 100 ppm of 500 kbit/s allows for the bit clock to be in the range of 500 kHz ± 50 Hz.

3.21
D9 — bit error ratio for communication
maximum allowed bit error ratio valid within the dynamic range of the receiver as defined by D11a and D11b

3.22
D10 — wake-up trigger for OBU
signal which:

a) indicates to the OBU that it is within a communication zone, i.e. that it can now communicate with an RSU;

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b) switches the OBU main circuitry from sleep mode to the active mode

Note 1 to entry: This is a feature to allow the OBU to save battery power. It is not mandatory for an OBU to use a wake-up process.

3.23
D10a — maximum start time
maximum time between the reception of the wake-up trigger and the time when the OBU has switched to the active mode

3.24
D11 — communication zone
spatial region within which the incident power of the OBU has a dynamic range as defined by D11a and D11b

3.25
D11a — power limit for communication (upper)
upper level of incident power referred to a lossless isotropic antenna (0 dB) in front of the OBU

Note 1 to entry: This is the level below which, subject to D11b, communication is guaranteed with a specified bit error ratio. Communication can take place above this limit, but is not guaranteed. Together with D11b it also specifies the minimum dynamic range of the OBU receiver. Power values are measured without any additional losses due to rain or misalignment.

3.26
D11b — power limit for communication (lower)
lower level of incident power referred to a lossless isotropic antenna (0 dB) in front of the OBU

Note 1 to entry: This is the level above which, subject to D11a, communication is guaranteed with a specified bit error ratio. Communication can take place below this limit, but is not guaranteed. Together with D11a it also specifies the minimum dynamic range of the OBU receiver. Power values are measured without any additional losses due to rain or misalignment

3.27
D12 — cut-off power level of OBU
incident power that is lower than the specified cut-off power level that does not result in communication

3.28
D13 — preamble
specific downlink layer 1-bit pattern

Note 1 to entry: Preamble is the bit pattern transmitted immediately before a frame.

3.29
D13a — preamble length
length of the downlink preamble measured in number of bits

3.30
D13b — preamble wave form
signal shape of the preamble

3.31
D13c — trailing bits
sequence of bits transmitted after the end flag of the data link layer

3.32
downlink
communication channel on which the fixed equipment transmits its information

3.33
downlink communication
communication from the RSU to the OBU

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3.34
equivalent isotropically radiated power
E.I.R.P.
signal power fed into an ideal lossless antenna radiating equally in all directions that generates the same power flux at a reference distance as the one generated by a signal fed into the antenna under consideration in a predefined direction within its far field region

3.35
fixed equipment
fixed communication facility with one or more downlink channels and, optionally, one or more uplink channels

Note 1 to entry: Normally the fixed equipment is installed at a fixed location, but it may be installed on a mobile platform.

3.36
interlayer management
assembly of communication parameters of all protocol layers such that a consistent communication protocol is provided

3.37
link identifier
LID
unique address used for addressing the mobile equipment

3.38
mobile equipment
mobile communication facility capable of receiving information from the fixed equipment on the downlink and, optionally, also capable of transmitting information to the fixed equipment on the uplink

Note 1 to entry: The mobile equipment normally corresponds to the vehicle's communication unit.

3.39
on-board unit
OBU
physical assembly that is located and operated in or on the vehicle to transmit and/or receive SDTC signals

Note 1 to entry: An OBU may be in a form that is removable from the vehicle, or mountable in or on any part of the vehicle structure, or bonded to a part of the vehicle, or an integral part of a vehicle component, such as a windscreen, bumper or licence plate. In this document, parameters that refer to an OBU relate to the form that the OBU takes as it is supplied to the vehicle manufacturer or constructor.

Note 2 to entry: An OBU is an alternative descriptor to Mobile Equipment.

3.40
roadside unit
RSU
SDTC equipment usually residing by the side of the road or overhead the road

Note 1 to entry: An RSU is an alternative descriptor to Fixed Equipment.

3.41
SDTC channel
frequency band for SDTC indicated by reference to the downlink centre frequency of one of up to four frequency bands with 5 MHz width each

3.42
SDTC profile
consistent and standardized set of cross layer parameters controlling the behaviour of the SDTC

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3.43
service access point
SAP
interface point between data link layer and application layer, that has a unique link identifier and that allows layers to communicate

3.44
smart digital tachograph communication
SDTC
CEN DSRC applied for the Smart Digital Tachograph (SDT)

Note 1 to entry: This is as identified by Regulation 2016/799 of the European Union[23].

3.45
termination
procedure used to terminate communication between an RSU and an OBU

3.46
U1 — sub-carrier frequencies
number and values of the uplink sub-carrier frequencies, i.e. the frequency separation from the centre of the uplink side band to the centre of the corresponding downlink band

3.47
U1a — tolerance of sub-carrier frequencies
maximum deviation of the sub-carrier frequency resulting from any cause

EXAMPLE 1 % of 1,5 MHz sub-carrier allows for the sub-carrier frequency to be in the range of 1,5 MHz ± 15 kHz.

Note 1 to entry: Normally this is expressed in percentage (%) or in parts per million (ppm) of the sub-carrier frequency.

Note 2 to entry: Terms prefixed with U present uplink parameters; uplink parameters apply to transmission of data from OBU to RSU.

3.48
U1b — use of side bands
specification of the use of the uplink side bands

Note 1 to entry: Data can be modulated on the upper side band only, or the lower side band only, or on both side bands. In principle, different data can be modulated on the two side bands.

3.49
U2 — OBU transmitter spectrum mask
maximum allowed power emitted by the OBU transmitter within a defined frequency band

3.50
U4 — maximum single side band E.I.R.P. (bore sight)
maximum E.I.R.P. transmitted by the OBU within a single side band, measured at the maximum incident power defined by D11a

Note 1 to entry: For a non-isotropic OBU antenna the single side band E.I.R.P varies with the direction of the incident power and the direction in which the emitted power is measured.

3.51
U4a — maximum single side band E.I.R.P. (bore sight)
measurement when the incident power is in bore sight and the emitted power is measured in bore sight

3.52
U4b — maximum single side band E.I.R.P. (35°)
measurement when the incident power is in bore sight and the emitted power is measured at any angle not less than 35° away from bore sight

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3.53
U5
uplink parameter indicating the uplink polarization

3.54
U5 — cross-polarization
uplink parameter indicating the cross-polarization

3.55
U6 — sub-carrier modulation
keying of the sub-carrier wave by coded data

EXAMPLE Amplitude shift keying (ASK), phase shift keying (PSK), and frequency shift keying (FSK).

Note 1 to entry: U6b is not used.

3.56
U6b — duty cycle
ratio of the length of high or low pulses to the duration of a complete cycle

Note 1 to entry: In NRZI a sequence of zero bits results in a pulse of alternating high- and low-level sections. A low-level section and the adjacent high-level section constitute a cycle of the pulse. The nominal duration of such a single section is equal to the bit duration. The cycle duration is twice the bit duration. The duty cycle is the ratio of the duration of the high-level section to the cycle duration.

3.57
U6c — modulation on carrier
keying of the carrier wave by the modulated sub-carrier

3.58
U7 — data coding
uplink base band signal presentation, i.e. a mapping of logical bits to physical signals

3.59
U8 — bit rate
number of bits per second, independent of the data coding

3.60
U8a — tolerance of symbol clock
maximum uplink deviation of the bit clock resulting from any cause, expressed in ppm

3.61
U9 — bit error ratio for communication
maximum allowed bit error ratio valid within the dynamic range of the receiver

3.62
U11 — communication zone
spatial region within which the OBU is situated such that its transmissions are received by the RSU with a bit error ratio of less than a specified value

3.63
U12 — conversion gain
difference between OBU E.I.R.P. within one side band and the carrier incident power on OBU

3.64
U13 — preamble
specific uplink layer 1-bit pattern

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3.65
U13a — preamble length
length of the uplink preamble

Note 1 to entry: Preamble length is measured either in multiples of symbols or in seconds.

3.66
U13b — trailing bits
sequence of bits transmitted after the end flag of the data link layer

3.67
uplink
communication channel on which mobile equipment transmits its information

3.68
uplink communication
communication from the OBU to the RSU

3.69
vehicle service table
VST
data structure transmitted by the OBU to indicate available services

3.70
window
period of time during which the physical medium is allocated either to the fixed equipment or to the mobile equipment

4 Abbreviated terms and symbols

2-PSK	binary phase shift keying
ACK	acknowledge
ACn	acknowledged command with sequence bit n
ADU	application data unit
AM	amplitude modulation
APDU	application protocol data unit
ASDU	application service data unit
ASK	amplitude shift keying
C/R	command/response
CEN	European Committee for Standardization
CEPT	European Conference of Postal and Telecommunications Administrations
CW	continuous wave
DLL	data link layer
DSRC	dedicated short-range communication
EC	European Commission

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EDTC	European digital tachograph communication
EFC	electronic fee collection
EN	European Standard
ERC	European Radiocommunications Committee
ERM	electromagnetic compatibility and radio spectrum matters
ETSI	European Telecommunications Standards Institute
F	final
FCS	frame check sequence
FE	fixed equipment
FM0 / FM1	bi-phase coding scheme, bit inverse to FM1 / FM0
FSK	frequency shift keying
HDLC	high-level data link control
ISM	industrial, scientific, medical
L1	layer 1 of SDTC (physical layer)
L2	layer 2 of SDTC (data link layer)
L7	layer 7 of SDTC (application layer)
LLC	logic link control
LPDU	link layer protocol data unit
LSB	least significant bit
LSDU	link layer service data unit
M	modifier function bit
MAC	medium access control
ME	mobile equipment
MSB	most significant bit
NRZ	non-return to zero
NRZI	non-return to zero inverted
OSI	open systems interconnection
P	poll
P/F	poll/final
PICS	protocol implementation conformance statement
PDU	protocol data unit

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PPDU	physical layer protocol data unit
PSDU	physical layer service data unit
ppm	parts per million
PSK	phase shift keying
R	response
R&TTE	radio and telecommunications terminal equipment
RR	response request
RTTT	road transport and traffic telematics
TDMA	time division multiple access
TSS&TP	test suite structure and test purposes
UI	unnumbered information
V_{rx}	receive state variable (LLC)
V_{tx}	transmit state variable (LLC)
XPD	cross-polar discrimination

5 Digital tachograph interrogation

5.1 General

A regulatory device such as a smart tachograph needs to offer an interface for interrogation by authorized officers. Such an interface may be carried through a physical connector, or via a wireless communication interface. When the second option is chosen, stringent requirements of confidentiality and, in general, security, arise.

A DSRC helps in satisfying these security requirements because of its localized nature and because of the experience already gained in securing this type of links. This is one of the reasons the specification of the application for digital tachograph interrogation in ISO 15638-9 is based on this type of communication mechanism.

Some legislations require that a radio link shall be available in smart tachograph devices, such as in Europe, where Regulation 165/2014[21] requires that "*In order to facilitate targeted roadside checks by the competent control authorities, tachographs installed in vehicles ... shall be able to communicate to those authorities while the vehicle is in motion*".

The right to allocate frequencies for DSRC and to determine suitable protocols for interrogation applications is left to regional legislation.

In Europe the frequency band of 5,8 GHz has been in use for EFC applications for example for many years. The communication and application layers defined for EFC are also suitable for other types of short range radio interrogations, such as that for the digital tachograph, and that which is required in Annex 14 of the Smart Tachograph Implementing Regulation of the EU [22]. The requirements on lower layers for the European digital tachograph are thus expressed in 5.2 and 5.3.

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5.2 SDTC protocol stack

5.2.1 Simplified OSI layered

SDTC is based on a simplified OSI layered model presented in Figures 1 and 2. The OSI Layers 3 (Network) and 4 (Transport) do not exist, as SDTC concerns localized communications, i.e. not providing routing of packets through a network.

NOTE The definition of "localized communications" can be found in ISO 21217. However, ISO 21217 is not needed for the understanding of this document, or for an interoperable implementation of SDTC.

Functionality of OSI Layers 5 (Session), 6 (Presentation) and 7 (Application) is provided in the SDTC Layer, application layer (L7).

The OSI Layer 1 maps to the SDTC Layer, physical layer (L1), and the OSI Layer 2 maps to the SDTC Layer, data link layer (L2).

Details of the digital tachograph application, which resides on top of L7, are out of the scope of this document. For details of the SDTC Layers, see 5.2.2, 5.2.3, 5.2.4 and 5.3.

5.2.2 SDTC L1

The SDTC physical layer specifications for the required 5,8 GHz DSRC shall be as specified in Annex A of this document.

5.2.3 SDTC L2

The SDTC data link layer procedures shall be as specified in Annex B of this document.

5.2.4 SDTC L7

The SDTC application layer to be used as a support for the digital tachograph interrogation shall be as specified in Annex C of this document.

5.3 SDTC profiles

The specification of SDTC L1, L2 and L7 allows for different implementations. To avoid ambiguity and non-interoperable implementations, a choice of options referred to as "SDTC profiles" shall be as specified in Annex D of this document.

6 Test methods

The exact specification of conformance testing procedures is left to national regulations. However, it is worthwhile noting here that the following conformance testing standards are available for all requirement standards listed in Clause 5, and in Annex A, Annex B, Annex C, and Annex D, and can be used in national certification procedures:

a) For the physical layer, including testing Layer 1 requirements specified in the profiles in Annex D:

   1) ETSI EN 300 674-1[12] for the general test procedures and test environment setup;

   2) ETSI EN 300 674-2-1[13] for the roadside unit;

   3) ETSI EN 300 674-2-2[14] for the roadside unit.

b) For the data link layer, including testing Layer 2 requirements specified in the profiles in Annex D:

   1) ETSI TS 102 486-1-1[15] for the protocol implementation conformance statement (PICS);

   2) ETSI TS 102 486-1-2[16] for the test suite structure and test purposes (TSS&TP);

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3) ETSI TS 102 486-1-3[17] for the abstract test suite and partial PIXIT proforma.

c) For the application layer, including testing Layer 7 requirements specified in the profiles in Annex D:

1) ETSI TS 102 486-2-1[18] for the protocol implementation conformance statement (PICS);

2) ETSI TS 102 486-2-2[19] for the test suite structure and test purposes (TSS&TP);

3) ETSI TS 102 486-2-3[20] for the abstract test suite and partial PIXIT proforma.

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Annex A
(normative)

SDTC physical layer

A.1 Overview and relation to CEN EN 12253

This annex:

— specifies the physical layer at 5,8 GHz for SDT Communications (SDTC); and

— provides requirements for the communication medium to be used for exchange of information between roadside units (RSUs) and on-board units (OBU);

It provides specifications equivalent to those published in CEN EN 12253[1] and as used in the specification for the Digital Tachograph; see ISO 15638-9, Reference [21] and Reference [22].

The terms "SDTC" and "DSRC" used in this annex are synonymous in terms of their applicability for the SDT.

A.2 SDTC link parameters

A.2.1 General

This clause defines relevant downlink and uplink parameters of the SDTC OSI Layer 1 (physical layer). The values to be used shall be set in accordance with SDTC profiles defined in Annex D.

OSI Layer 1 parameters are measured for free space propagation. Attention is drawn to the definition of an OBU in 3.38, which means that measurements are taken in the absence of a windscreen or other obscuring material unless it forms part of the manufactured OBU assembly.

A.2.2 Downlink parameters

Table A.1 shows downlink parameters.

Table A.1 — Downlink parameters

Item No.	Parameter	Value(s)	Remark
D1	Carrier frequencies	Two downlink channels at: Downlink channel 1: 5,797 5 GHz Downlink channel 2: 5,802 5 GHz	Other 10 MHz bands within the same ISM band allocated for RTTT on a national basis: Downlink channel 3: 5,807 5 GHz Downlink channel 4: 5,812 5 GHz These channels are defined in accordance with ECC/DEC(02)01[10]. The selection of carrier frequencies is outside the scope of this document.

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Table A.1 *(continued)*

Item No.	Parameter	Value(s)	Remark
D1a	Tolerance of carrier frequencies	Within ±5 ppm	
D2	RSU transmitter spectrum mask	1) Out band power: see ETSI EN 300 674-1[12] 2) In band power: ≤ +33 dBm 3) Unwanted emission for unmodulated carrier wave shall be less than: Co-channel uplink at 1,5 MHz: ≤ -27 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -47 dBm in 500 kHz.	
		4) For in-band unwanted emission with modulated carrier wave, three different requirement classes are defined:	Equipment conforming with the different classes results in different re-use distances. See ETSI EN 300 674-1[12] for more details
		Class A: Co-channel uplink at 1,5 MHz: ≤ -7 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -30 dBm in 500 kHz.	*Class A* is originally specified in the respective CEN European Norm, indicating that this *Class A* should not be used in new installations. Further on, it is not considered for the European Digital Tachograph.
		Class B: Co-channel uplink at 1,5 MHz: ≤ -17 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -37 dBm in 500 kHz.	
		Class C: Co-channel uplink at 1,5 MHz: ≤ -27 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -47 dBm in 500 kHz.	
D3	OBU Minimum Frequency Range	5,795 GHz – 5,815 GHz	
D4	Maximum E.I.R.P.	+33 dBm	
D4a	Angular E.I.R.P. mask	Θ ≤ 70°: ≤ +33 dBm Θ > 70°: ≤ +18 dBm	
D5	Polarization	Left-hand circular	

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Table A.1 *(continued)*

Item No.	Parameter	Value(s)	Remark
D5a	Cross-polarization	XPD: In bore sight: $RSU_t \geq 15$ dB $OBU_r \geq 10$ dB At -3 dB area: $RSU_t \geq 10$ dB $OBU_r \geq 6$ dB	
D6	Modulation	Two level amplitude modulation.	
D6a	Modulation index	0,5 - 0,9	
D7	Data coding	FM0 "1" bit has transitions only at the beginning and end of the bit interval. "0" bit has an additional transition in the middle of the bit interval compared to the "1" bit.	
D8	Bit rate	500 kbit/s	
D8a	Tolerance of bit clock	Better than ±100 ppm	
D9	Bit error ratio for communication	$\leq 10^{-6}$ when incident power at OBU is in the range given by [D11a to D11b].	
D10	Wake-up trigger for OBU	OBU shall wake up on receiving any frame with 11 or more octets (including preamble).	No special wake-up pattern is necessary. OBU may wake up on receiving a frame with less than 11 octets.
D10a	Maximum start time	≤ 5 ms	
D11	Communication zone	Spatial region within which a bit error ratio according to D9 is achieved.	
D11a	Power limit for communication (upper)	Incident power: D11a-0: -24 dBm D11a-1: -17 dBm	Implemented values are subject to profiles and sets defined in Annex D.
D11b	Power limit for communication (lower)	Incident power: -43 dBm	
D12	Cut-off power level of OBU	-60 dBm	Applicability of this parameter is subject to profiles and sets defined in Annex D.
D13	Preamble	Preamble is mandatory.	
D13a	Preamble length	16 bits ± 1 bit	
D13b	Preamble wave form	An alternating sequence of low level and high level with pulse duration of 2 µs. The tolerance is given by D8a.	
D13c	Trailing bits	The RSU is permitted to transmit a maximum of 8 bits after the end flag. An OBU is not required to take these additional bits into account.	

A.2.3 Uplink parameters

Table A.2 shows uplink parameters.

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