The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

NON-COHERENT OPTICAL COMMUNICATIONS PHYSICAL LAYER

RECOMMENDED STANDARD

CCSDS 141.0-B-2

BLUE BOOK
March 2026

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Email: secretariat@mailman.ccsds.org

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  - -- The anticipated date of initial operational capability.
  - -- The anticipated duration of operational service.
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In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

FOREWORD

This document is a CCSDS Recommended Standard for the Physical Layer of signals to be used in optical communications systems of space missions. The Physical Layer concepts described herein are intended for missions that are cross supported between Agencies of the CCSDS.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in the *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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– Swedish Space Corporation (SSC)/Sweden.
– Swiss Space Office (SSO)/Switzerland.
– United States Geological Survey (USGS)/USA.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 141.0-B-1	Optical Communications Physical Layer, Recommended Standard, Issue 1	August 2019	Original issue
CCSDS 141.0-B-2	Non-Coherent Optical Communications Physical Layer, Recommended Standard, Issue 2	March 2026	Adds specifications for optical on-off keying

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to specify the Physical Layer characteristics of free-space optical communications systems used by space missions. This issue of the Recommended Standard primarily applies to space-to-ground and ground-to-space links through atmospheric channels, but it may also be applied to other operating conditions. When provided with a sequence of pulsed and non-pulsed slots produced by the Coding and Synchronization sublayer (see reference [1]), this specification describes the required Physical Layer characteristics of the signal transmission.

1.2 SCOPE

This Recommended Standard defines Physical Layer schemes in terms of the signal characteristics and procedures involved in the physical transmission of the optical signals. It does not specify:

a) individual implementations or products;

b) methods or technologies required to perform the procedures; or

c) management activities required to configure and control the system.

This Recommended Standard provides a specification for two regimes of optical communications. In one regime, High Photon Efficiency (HPE) optical communications, the photon-efficiency of the link is of primary concern. Details of the design and implementation of HPE systems can be found in references [D5], [D6], and [D7]. In the second regime, Optical On-Off-Keying (O3K), low complexity is of primary concern. The primary application of O3K focusses on optical downlinks from Low Earth Orbiting satellites.

1.3 APPLICABILITY

This Recommended Standard applies to the creation of Agency standards and to the future data communications over optical space links between CCSDS Agencies in cross-support situations. It includes comprehensive specifications of the data formats and procedures for inter-Agency cross support. It is neither a specification of, nor a design for, real systems that may be implemented for existing or future missions.

The Recommended Standard specified in this document is to be invoked through the normal standards program of each CCSDS Agency and is applicable to those missions for which cross support based on capabilities described in this Recommended Standard is anticipated. Where mandatory capabilities are clearly indicated in sections of this Recommended Standard, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4 RATIONALE

The rationale for producing this Recommended Standard stems from the need to facilitate cross support at the physical layer of optical communications systems used by CCSDS member agencies. Such cross support requires specifying allowable center frequencies of transmission and other physical layer characteristics of the signal.

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. The rationale for the specifications making up this Recommended Standard is expected to be documented in a forthcoming CCSDS Informational Report.

1.5 DOCUMENT STRUCTURE

This document is divided into seven numbered sections and four annexes:

a) section 1 presents the purpose, scope, applicability, rationale, document structure, definitions, and references;

b) section 2 provides an overview of the architecture and summary of functions of the Physical Layer;

c) section 3 specifies HPE telemetry signal characteristics;

d) section 4 specifies HPE beacon and optional accompanying data transmission signal characteristics;

e) section 5 specifies O3K telemetry signal characteristics;

f) section 6 specifies O3K beacon and optional data transmission signal characteristics;

g) section 7 lists the managed parameters;

h) annex A is a Protocol Implementation Conformance Statement (PICS) Proforma;

i) annex B discusses security issues;

j) annex C lists acronyms used within this document;

k) annex D provides a list of informative references.

1.6 TERMS

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

center frequency: The central frequency of a laser beam occupying a range of frequencies.

laser linewidth: The spectral linewidth of a laser beam.

optical pulse: An emission of photons, often constrained with respect to its amplitude, shape, and duration.

polarization extinction ratio: The ratio of optical powers of perpendicular polarization.

pulse repetition rate, PRR: The number of emitted pulses per second, or the inverse temporal pulse spacing.

right-hand circular polarization, RHCP: A circularly polarized wave in which the electric field vector rotates in a right-hand sense, with respect to the direction of propagation.

spillover emissions: The energy of an emission that is outside of a defined spectral band.

1.7 NOMENCLATURE

1.7.1 NORMATIVE TEXT

The following conventions apply throughout this Specification:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.7.2 INFORMATIVE TEXT

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Background;

– Rationale;

– Discussion.

1.8 CONVENTIONS

In this document, the following convention identifies each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left-justified when drawing a figure) is defined to be ‘Bit 0’, the following bit is defined to be ‘Bit 1’, and so on up to ‘Bit *N*-1’. When the field is used to express a binary value, such as a counter, the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., ‘Bit 0’ (see figure 1-1).

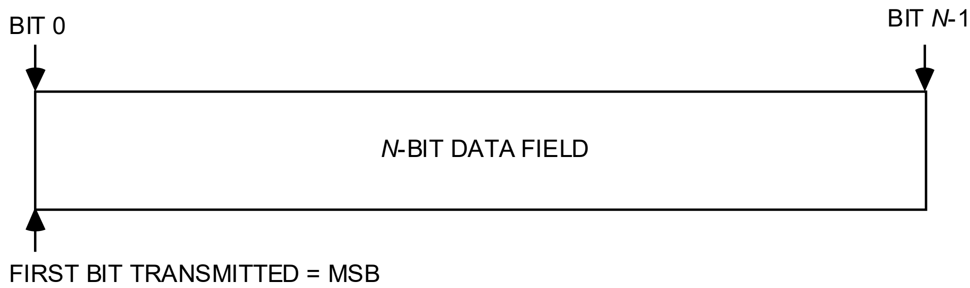

Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit 'words' which conform to the above convention. Throughout this specification, such an 8-bit word is called an 'octet'. The numbering for octets within a data structure starts with '0'.

NOTE – Throughout this document, 'bit' refers to the contents of the transfer frames. A bit is a binary digit transferred between the Data Link Protocol sublayer and the Coding and Synchronization sublayer. Other symbols, whether binary or nonbinary, will be referred to by other names, such as 'binary digits'. It should be understood that the ordering conventions described above apply equally to other types of symbols.

1.9 REFERENCES

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

[1] *Non-Coherent Optical Communications Coding and Synchronization*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 142.0-B-2. Washington, D.C.: CCSDS, March 2026.

[2] *IEEE Standard for Definitions of Terms for Antennas*. Revision of IEEE Std 145-1993. IEEE Std 145-2013. New York: IEEE, 2014.

2 OVERVIEW

2.1 ARCHITECTURE

Figure 2-1 illustrates the relationship of this Recommended Standard to the Open Systems Interconnection (OSI) reference model (reference [D1]). Two sublayers of the Data Link Layer are defined for CCSDS space link protocols. The Data Link Protocol sublayer provides functions for producing Transfer Frames; possible Space Data Link Protocols using optical communications are the Telemetry (TM) Space Data Link Protocol (reference [D2]), the Advanced Orbiting Systems (AOS) Space Data Link Protocol (reference [D3]), and the Unified Space Data Link Protocol (USLP) (reference [D8]). The Non-Coherent Optical Coding and Synchronization protocol (reference [1]) provides the functions of the Coding and Synchronization sublayer of the Data Link Layer for transferring Transfer Frames over an optical space link. The Non-Coherent Optical Communications Physical Layer specified in this Recommended Standard provides the required characteristics of the Physical Layer transmission from space to ground and from ground to space.

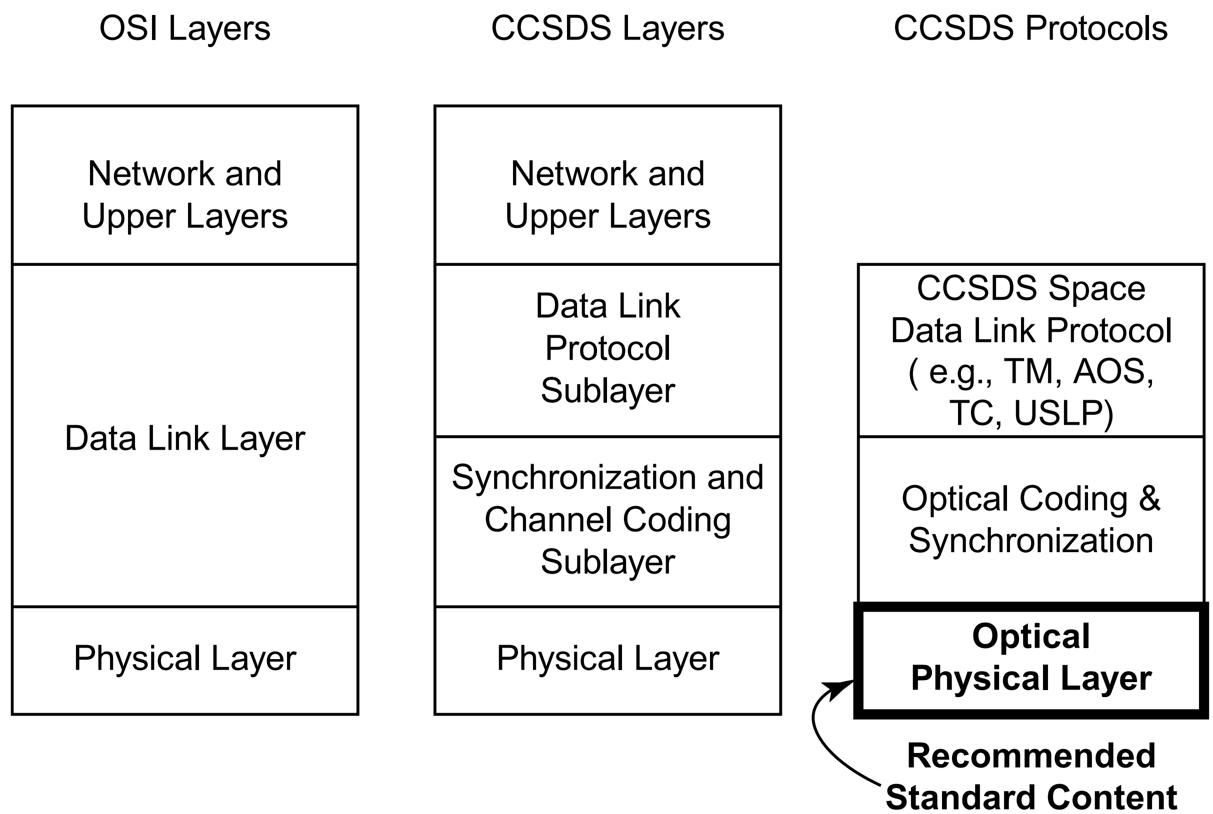

Figure 2-1: Relationship with OSI Layers

2.2 SUMMARY OF FUNCTIONS

The Optical Communications Physical Layer specifies the physical characteristics of the telemetry signal and, separately, the physical characteristics of the beacon and optional telecommand signal. In a typical application, a spacecraft transmits telemetry to a ground station, and a ground station transmits a beacon and optional transfer frames to the spacecraft.

For each of the telemetry, beacon, and optional data transmission specifications, this Recommended Standard defines the transmission laser's required center frequency, tuning range, linewidth, in-band and spillover emissions, polarization, modulation, pulse shape, timing jitter, and supported slot widths.

The overall architecture of the optical communications system is shown in figure 2-2. Throughout the communications session, the optical Terminal A transmits a beacon, together with optional AOS or USLP transfer frames. The Terminal B receiver locks onto the beacon and uses it to assist in pointing its optical transmitter accurately. Additionally, any AOS/USLP transfer frames are decoded onboard. Telemetry is transmitted from terminal B and received by Terminal A. This Recommended Standard specifies the physical characteristics of the Terminal A and Terminal B transmitters. In a typical application, Terminal A on the ground transmits an uplink beacon and optional AOS/USLP transfer frames to Terminal B in space, and Terminal B transmits a downlink telemetry signal to Terminal A.

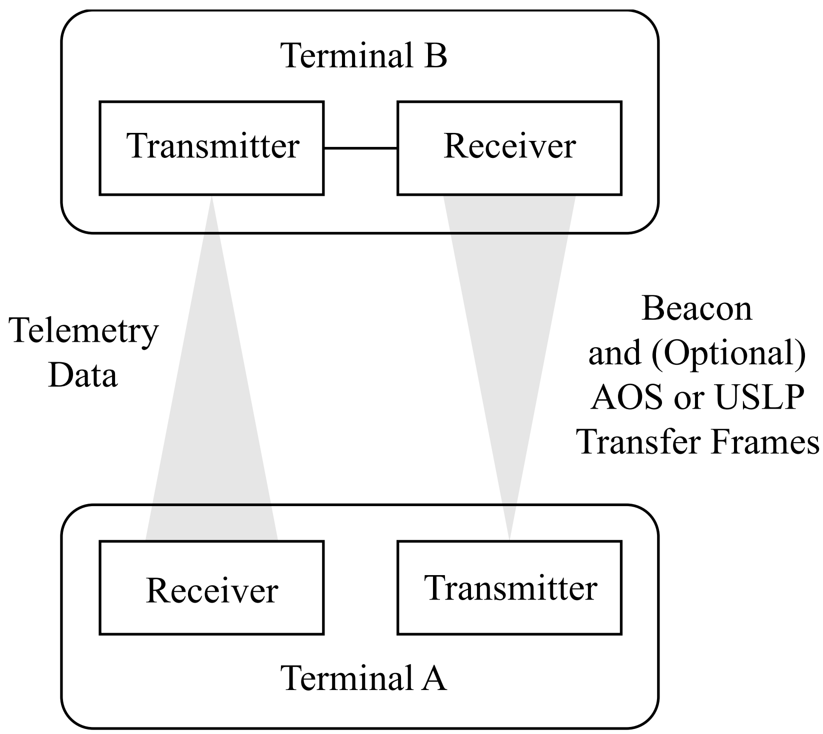

Figure 2-2: Overall Architecture of the Optical Communications System

3 HPE TELEMETRY SIGNAL CHARACTERISTICS

3.1 OVERVIEW

The sending end receives a binary vector from the Coding and Synchronization sublayer, as defined in reference [1], indicating a sequence of slots in which light pulses are to be present (1) or absent (0). The physical characteristics of these pulses at the sending end are described below. At the receiving end, the Physical Layer delivers slot measurements to the Coding and Synchronization sublayer.

3.2 CENTER FREQUENCY

The center frequency shall be 193.1 + n×0.1 THz, where n is an integer ranging from −18 to 28.

NOTE – These center frequencies in the optical C-band are a subset of those defined by the International Telecommunication Union (ITU) in ITU-T G.694.1 frequency grid with 100 GHz channel spacing (reference [D4]). The frequencies range from 191.3 THz to 195.9 THz and correspond to wavelengths in a vacuum ranging from 1530.33 nm to 1567.13 nm.

3.3 CENTER FREQUENCY TOLERANCE

The transmitter center frequency shall be accurate to within a tolerance of ± 10 GHz.

3.4 LASER LINEWIDTH

The modulated laser linewidth shall be less than 6.25 GHz, measured at full width, $1/e^2$ of maximum, over a time scale of 100 ms.

3.5 IN-BAND AND SPILLOVER EMISSIONS

The laser shall transmit 95 percent of its energy within ± 10 GHz of its center frequency.

3.6 POLARIZATION

3.6.1 POLARIZATION TYPE

Polarized laser emission is optional. When polarized, the laser emission exiting the terminal aperture shall be Right-Hand Circularly Polarized (RHCP) as defined in reference [2].

3.6.2 POLARIZATION EXTINCTION RATIO

When polarized emission is used, the polarization extinction ratio shall be greater than 10 dB.

3.7 MODULATION

The binary vector received from the Coding and Synchronization sublayer defined in reference [1] shall be used to modulate the intensity of emitted light within each slot, using On-Off Keying (OOK).

NOTE – A modulation of Pulse Position Modulation (PPM) at the Coding and Synchronization sublayer gives rise to OOK at the Physical Layer, in the sense that a light pulse is present or absent in each slot.

3.8 TIMING JITTER

The Root Mean Square (RMS) pulse timing jitter shall be less than 10 percent of the slot width.

3.9 SLOT WIDTH

The slot width *T* shall be 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256, or 512 ns.

3.10 PULSE REPETITION RATES

The laser shall support a range of Pulse Repetition Rates (PRRs) corresponding to the slot width(s) and PPM order(s) used by the communications link.

NOTE – For example, in a system using 1 ns slots with 16-PPM and 4 slots of guard time, pulses could be as close as 5 ns and as far apart as 35 ns, center to center, corresponding to a PRR range of 28.57 to 200 MHz.

4 HPE BEACON AND OPTIONAL ACCOMPANYING DATA TRANSMISSION SIGNAL CHARACTERISTICS

4.1 OVERVIEW

When data transmission accompanies the HPE beacon signal, the sending end receives a binary vector from the Coding and Synchronization sublayer, as defined in reference [1], indicating a sequence of slots in which light pulses are to be present (1) or absent (0). The physical characteristics of these pulses at the sending end are described below. At the receiving end, the Physical Layer delivers slot measurements to the Coding and Synchronization sublayer.

4.2 CENTER FREQUENCY

The center frequency shall be tunable to any frequency within ±26 GHz of 280.18 THz, 281.72 THz, or 291.06 THz.

NOTE – These center frequencies correspond to wavelengths in vacuum of 1070 nm, 1064.15 nm, and 1030 nm, respectively.

4.3 CENTER FREQUENCY TOLERANCE

The transmitter center frequency shall be accurate to within a tolerance of ±26.5 GHz.

4.4 LASER LINEWIDTH

The laser linewidth shall not exceed 53 GHz, measured at full width $1/e^2$ of maximum, over a time scale of 100 ms.

4.5 IN-BAND AND SPILLOVER EMISSIONS

The laser shall transmit 95 percent of its energy within ±50 GHz of its center frequency.

4.6 MODULATION

4.6.1 OVERVIEW

Data transmission is optional.

4.6.2 WHEN DATA TRANSMISSION IS NOT USED

When data transmission is not used, the beacon transmission shall be a 3.8145 kHz square wave. The period of the square wave is 262,144 ns, that is, an alternating sequence of pulsed and non-pulsed slots of duration 131,072 ns.

4.6.3 WHEN DATA TRANSMISSION IS USED

4.6.3.1 General

When data transmission is used, the binary vector received from the Coding and Synchronization sublayer defined in reference [1] shall be used to modulate the intensity of emitted light within each slot, using OOK.

NOTES

1 A modulation of PPM at the Coding and Synchronization sublayer gives rise to OOK at the Physical Layer, in the sense that a light pulse is present or absent in each slot.

2 The transmission is not required to be polarized.

4.6.3.2 Slot Widths

The slot width shall be 65,536 ns.

NOTE – This Recommended Standard can be compatible with systems using substantially narrower pulse shapes that convey additional, higher-rate telecommand data than is specified in this Recommended Standard. Such ‘nested outer modulations’ are not specified by this Recommended Standard, but they are not necessarily precluded by it.

4.7 TIMING JITTER

The RMS pulse timing jitter shall be less than 10 percent of the slot width.

5 OPTICAL ON-OFF KEYING TELEMETRY SIGNAL CHARACTERSTICS

5.1 OVERVIEW

Sections 5 and 6 are intended to enable vendors and operators to provide compatible laser communication equipment and services for O3K systems, mainly for use with, but not limited to, high-speed optical direct-to-Earth telemetry data downlinks. At the sending end, a binary vector is received from the Coding and Synchronization sublayer, as defined in reference [1], indicating a sequence of slots in which light pulses are to be present (1) or absent (0). The physical characteristics of these transmitted pulses are described below. At the receiver, the Physical Layer demodulates the data and delivers statistics to the Coding and Synchronization sublayer for its use in decoding.

5.2 CENTER FREQUENCIES

The center frequency shall be $193.1 + n \times 0.1$ THz, where n is an integer ranging from −18 to 28 for choosing one of 47 optional bands for communications downlink.

NOTES

1 The value of n is a managed parameter.

2 These center frequencies in the optical C-band are a subset of those defined in the ITU-T G.694.1 frequency grid with 100 GHz channel spacing (reference [D4]). The frequencies range from 191.3 THz to 195.9 THz, corresponding to wavelengths in a vacuum ranging from 1530.33 nm to 1567.13 nm.

5.3 CENTER FREQUENCY TOLERANCE

The transmitter center frequency shall be accurate to within a tolerance of ±10 GHz.

5.4 LASER LINEWIDTH

The modulated laser linewidth shall be less than 10 GHz, measured as full width at half-maximum, over a time scale of 100 ms.

5.5 IN-BAND AND SPILLOVER EMISSIONS

The laser shall transmit 95 percent of its energy within ±20 GHz of its center frequency.

5.6 MODULATION

5.6.1 MODULATION SCHEME

On-Off Keying Non-Return-to-Zero (OOK-NRZ) with equal lengths of ones and zeros slots shall be used as the modulation scheme for telemetry.

5.6.2 PULSE SHAPE/EYE DIAGRAM

The eye-pattern of the transmission shall not impinge on the geometrical shape shown in figure 5-1.

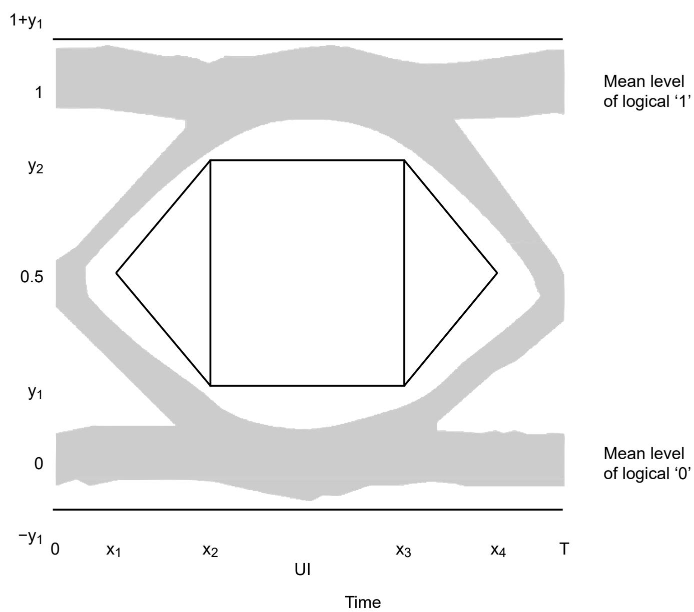

Figure 5-1: Transmit Eye-Pattern

T denotes the OOK slot width. In the figure, $x_1 = 0.1T$, $x_2 = 0.15T$, $x_3 = 0.85T$, $x_4 = 0.9T$, $y_1 = 0.1$ of the mean level of logical 0, and $y_2 = 0.9$ of the mean level of logical 1.

5.6.3 TIMING JITTER

The RMS pulse timing jitter shall be less than 10 percent of the slot width.

5.6.4 EXTINCTION RATIO

The extinction ratio shall be greater than 10 dB. The ratio is defined to be the ratio of the mean ON level to the mean OFF level.

5.7 SLOT WIDTH

The slot width T shall be one of 0.1×2^k ns, with $0 \leq k \leq 13$.

NOTES

1 The value of T is a managed parameter.

2 These slot widths correspond to channel symbol rates of $r = 10/2^k$ Gsym/s, with $0 \leq k \leq 13$.

6 OPTICAL ON-OFF KEYING BEACON AND OPTIONAL ACCOMPANYING DATA TRANSMISSION SIGNAL CHARACTERISTICS

6.1 OVERVIEW

The counter terminal transmits a beacon to the satellite terminal for better pointing accuracy. This beacon signal can optionally be used for data transmission.

6.2 CENTER FREQUENCIES

The center frequency shall be one of the following three choices:

a) between 188.350 THz (1591.68 nm) to 188.750 THz (1588.30 nm);

b) between 195.000 THz (1537.40 nm) to 195.900 THz (1530.33 nm);

c) between 370.112 THz (810 nm) to 371.948 THz (806 nm).

6.3 CENTER FREQUENCY TOLERANCE

For basic uplink beacon operations, the center frequency tolerance shall be ±50 GHz for options a) and b), and ±918 GHz for option c).

6.4 LASER LINEWIDTH

Measured as full width at half maximum over a time scale of 100 ms, the laser linewidth shall not exceed ±50 GHz for uplink center frequency options a) and b), and shall be in the range from ±50 GHz to ±300 GHz for option c).

6.5 IN-BAND AND SPILLOVER EMISSIONS

The laser shall transmit 95 percent of its energy within ±100 GHz of its center frequency for options a) and b), and ±1218 GHz for option c).

6.6 MODULATION

6.6.1 MODULATION SCHEME

Terminal-A shall transmit its beacon signal unmodulated (Continuous Wave [CW]) or modulated using rectangular or sinusoidal pulses with a major spectral component at one predefined frequency.

6.6.2 BEACON PULSE REPETITION RATE

6.6.2.1 The beacon signal shall be unmodulated (i.e., CW) or modulated.

6.6.2.2 If the beacon signal is modulated, the modulating frequency shall be in the interval of 1 kHz to 10 MHz for options a) and b), and 0 Hz to 10 kHz for option c).

NOTE – The beacon pulse repetition rate is a managed parameter.

6.6.3 TIMING JITTER

The RMS pulse timing jitter shall be less than 10 percent of the slot width.

6.6.4 EXTINCTION RATIO

The extinction ratio shall be greater than 10 dB. The extinction ratio is defined as the ratio of the mean ON level to the mean OFF level.

7 MANAGED PARAMETERS

7.1 HIGH PHOTON EFFICIENCY SIGNALING

The managed parameters for HPE signaling shall be those specified in table 7-1.

Table 7-1: Managed Parameters for HPE

Managed Parameter	Allowed Values
n, the telemetry signaling center frequency selection parameter	Integer in {−18, −17, …, 27, 28}
Telemetry signaling slot width	0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256, or 512 ns
Telemetry signaling polarized transmission	Used or Not Used
Beacon frequency	280.18, 281.72, or 291.06 THz
Data transmission	Used or Not Used

7.2 OPTICAL ON-OFF KEYING SIGNALING

The managed parameters for O3K signaling shall be those specified in table 7-2.

Table 7-2: Managed Parameters for Optical On-Off Keying

Managed Parameter	Allowed Values
n, the telemetry signaling center frequency selection parameter	Integer in {−18, −17, …, 27, 28}
Telemetry signaling slot width	0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8, 25.6, 51.2, 102.4, 204.8, 409.6, 819.2. ns
Beacon frequency	a) 188.350 THz to 188.750 THz b) 195.000 THz to 195.900 THz c) 370.112 THz to 371.948 THz
Beacon pulse repetition rate	1 kHz to 10 MHz, for options a) and b), and 0 Hz to 10 kHz for option c).

ANNEX A

PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the Protocol Implementation Conformance Statement (PICS) Requirements List (RL) for an implementation of Optical Communications Physical Layer, (CCSDS 141.0-B-2). The ICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation claiming conformance must satisfy the mandatory requirements referenced in the RL.

The RL support column in this annex is blank. An implementation's completed RL is called the ICS. The ICS states which capabilities and options have been implemented. The following can use the ICS:

– the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;

– a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard ICS proforma;

– a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICSes);

– a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

The RL consists of information in tabular form. The status of features is indicated using the abbreviations and conventions described below.

<u>Item Column</u>

The item column contains sequential numbers for items in the table.

Description Column

The description column contains a brief description of the item. It implicitly means 'Is this item supported by the implementation?'

Reference Column

The reference column indicates the relevant subsection of *Optical Communications Coding and Synchronization*, CCSDS 141.0-B-2 (this document).

Status Column

The status column uses the following notations:

M mandatory.

O optional.

O.*i* qualified optional – for a group of related optional items labeled by the same numeral *i*, it is mandatory to support at least one of the items.

C:<status> indicates that the status applies for the given subordinate item when the parent item is supported, and is not applicable otherwise.

1+ One or more of the allowed values must be supported.

N/A not applicable.

Support Column Symbols

The support column is to be used by the implementer to state whether a feature is supported by entering Y, N, or N/A, indicating:

Y Yes, supported by the implementation.

N No, not supported by the implementation.

N/A Not applicable.

The support column should also be used, when appropriate, to enter values supported for a given capability.

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

An implementer shows the extent of compliance to the Recommended Standard by completing the RL; that is, the state of compliance with all mandatory requirements and the options supported are shown. The resulting completed RL is called an ICS. The implementer shall complete the RL by entering appropriate responses in the support or values supported column, using the notation described in A1.2. If a conditional requirement is inapplicable, N/A should be used. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference X*i*, where *i* is a unique identifier, to an accompanying rationale for the noncompliance.

A2 ICS PROFORMA FOR OPTICAL COMMUNICATIONS CODING AND SYNCHRONIZATION (CCSDS 142.0-B-1)

A2.1 GENERAL INFORMATION

A2.1.1 Identification of ICS

Date of Statement (DD/MM/YYYY)	
ICS serial number	
System Conformance statement cross-reference	

A2.1.2 Identification of Implementation Under Test (IUT)

Implementation Name	
Implementation Version	
Special Configuration	
Other Information	

A2.1.3 Identification of Supplier

Supplier	
Contact Point for Queries	
Implementation Name(s) and Versions	
Other information necessary for full identification, e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	

A2.1.4 Identification of Specification

CCSDS 142.0-B-1	
Have any exceptions been required? NOTE – A YES answer means that the implementation does not conform to the Recommended Standard. Non-supported mandatory capabilities are to be identified in the ICS, with an explanation of why the implementation is nonconforming.	Yes [ ] No [ ]

A2.1.5 Requirements list

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
PHY-1	HPE or O3K supported	3, 4, 5, 6	1+	N/A	HPE, O3K

HPE Telemetry signaling:

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
HPE-1	Center frequency index	3.2	1+	Integer in {−18, −17, …, 27, 28}	
HPE-2	Center frequency tolerance	3.3	M	±10 GHz	
HPE-3	Laser linewidth	3.4	M	< 6.25 GHz	
HPE-4	In-band and spillover emissions	3.5	M	95% within ±10 GHz	
HPE-5	Polarized emission	3.6	O	N/A	
HPE-5.1	Polarization type	3.6.1	C:M	RHCP	
HPE-5.2	Polarization extinction ratio	3.6.2	C:M	> 10 dB	
HPE-6	Modulation	3.7	M	OOK	

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
HPE-7	Timing jitter	3.8	M	<10% of slot	
HPE-8	Slot width	3.9	M	0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256, or 512 ns	
HPE-9	PRRs	3.10	M	N/A	

HPE beacon and optional accompanying data transmission signaling:

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
HPE-10	Center frequency	4.2	1+	within ±26 GHz of 280.18, 281.72, 291.06 THz	
HPE-11	Center frequency tolerance	4.3	M	±26.5 GHz	
HPE-12	Laser linewidth	4.4	M	53 GHz	
HPE-13	In-band and spillover emissions	4.5	M	95% within ±50 GHz	
HPE-14	Telecommand data transmission not used	4.6.2	O.1	N/A	
HPE-14.1	Beacon	4.6.2	C:M	3.8145 kHz square wave	
HPE-15	Telecommand data transmission used	4.6.3	O.1	N/A	
HPE-15.1	Slot width	4.6.3.2	C:M	65,536 ns	
HPE-16	Timing jitter	4.7	M	< 10% of slot	

O3K Telemetry signaling:

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
O3K-1	Center frequency index	5.2	1+	Integer in {−18, −17, …, 27, 28}	
O3K -2	Center frequency tolerance	5.3	M	±10 GHz	
O3K -3	Laser linewidth	5.4	M	< 10 GHz	
O3K -4	In-band and spillover emissions	5.5	M	95% within ±20 GHz	
O3K -5.1	Modulation	5.6.1	M	OOK	
O3K -5.2	Timing jitter	5.6.3	M	< 10% of slot	
O3K-5.3	Extinction Ratio	5.6.4	M	> 10 dB ON/OFF ratio	
O3K -6	Slot width	5.7	1+	0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8, 25.6, 51.2, 102.4, 204.8, 409.6, or 819.2 ns	

When O3K telemetry signaling is used, the beacon signaling described in Section 6 is optional. When O3K beacon signaling is used, the following table applies:

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
O3K-1	Center frequency	6.2	1+	a) 188.350 THz to 188.750 THz b) 195.000THz to 195.900THz c) 370.112 THz to 371.948 THz	
O3K -2	Center frequency tolerance	6.3	M	±50 GHz for options a) and b) and ±918 GHz for option c)	

Item	Description	Reference	Status	Values Allowed	Item or Values Supported
O3K -3	Laser linewidth	6.4	M	±50 GHz for options a) and b), and ±50 GHz to ±300 GHz for option c)	
O3K -4	In-band and spillover emissions	6.5	M	95% within ±100 GHz for options a) and b), and ±1218 GHz for option c)	
O3K -5.1	Modulation	6.6.1	M	Unmodulated or OOK	
O3K-5.2	Beacon Pulse Repetition Rate	6.6.2	M	1 kHz to 10 MHz for options a) and b), and 0 to 10 kHz for option c)	
O3K -5.3	Timing jitter	6.6.3	M	< 10% of slot	
O3K -5.4	Extinction Ratio	6.6.4	M	> 10 dB max/min ratio	

ANNEX B

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

B1 SECURITY CONSIDERATIONS

B1.1 SECURITY BACKGROUND

It is assumed that security is provided by encryption, authentication methods, and access control performed at a layer above the physical layer and coding and synchronization sublayer. Mission and service providers are expected to select from recommended security methods, suitable to the specific application profile. Specification of these security methods and other security provisions is outside the scope of this Recommended Standard. The Physical Layer has the objective of delivering data with the minimum possible amount of residual errors. The associated channel coding as described in reference [1] must be used to ensure that residual errors are detected and the frame is flagged. There is an extremely low probability of additional undetected errors that may escape this scrutiny. These errors may impact the encryption process in unpredictable ways, possibly affecting the decryption stage and producing data loss, but will not compromise the security of the data.

B1.2 SECURITY CONCERNS

Security concerns in the areas of data privacy, authentication, access control, availability of resources, and auditing are addressed in higher layers and are outside the scope of this Recommended Standard.

B1.3 CONSEQUENCES OF NOT APPLYING SECURITY

There are no specific security measures prescribed for the Physical Layer. Therefore, consequences of not applying security are only imputable to the lack of proper security measures in other layers. Residual undetected errors may produce additional data loss when the link carries encrypted data.

B2 SANA CONSIDERATIONS

The recommendations of this document do not require any action from SANA.

B3 PATENT CONSIDERATIONS

No patents are known to relate to this Recommended Standard.

ANNEX C

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

AOS	Advanced Orbiting Systems
CW	continuous wave
HPE	high photon efficiency
ITU	International Telecommunication Union
MSB	most significant bit
NRZ	non-return-to-zero
O3K	optical on-off-keying
OOK	on-off keying
OSI	Open Systems Interconnection
PPM	pulse position modulation
PRR	pulse repetition rate
RHCP	right-hand circular polarization
RL	Requirements List
RMS	root mean square
TM	telemetry
USLP	Unified Space Data Link Protocol

ANNEX D

INFORMATIVE REFERENCES

[D1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[D2] *TM Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-3. Washington, D.C.: CCSDS, October 2021.

[D3] *AOS Space Data Link Protocol*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-5. Washington, D.C.: CCSDS, October 2025.

[D4] *Spectral Grids for WDM Applications: DWDM Frequency Grid*. ITU-T Recommendation G.694.1. Geneva: ITU, 2020.

[D5] B. Moision and J. Hamkins. "Coded Modulation for the Deep-Space Optical Channel: Serially Concatenated Pulse-Position Modulation." *IPN Progress Report* 42-161 (May 15, 2005).

[D6] Robert M. Gagliardi and Sherman Karp. *Optical Communications*. 2nd ed. Hoboken, New Jersey: Wiley, March 1995.

[D7] Hamid Hemmati, ed. *Deep Space Optical Communications*. Hoboken, New Jersey: Wiley, June 2006.

[D8] *Unified Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-3. Washington, D.C.: CCSDS, June 2024.