



BSI Standards Publication

Space engineering — SpaceFibre — Very high-speed serial link

National foreword

This British Standard is the UK implementation of EN 16603-50-11:2020.

The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its committee manager.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 00839 5

ICS 49.140

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2020.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English version

Space engineering - SpaceFibre - Very high-speed serial link

Ingénierie spatiale - SpaceFibre - Liaison série très haut débit

Raumfahrttechnik - SpaceFibre - Sehr schnelle serielle Schnittstelle

This European Standard was approved by CEN on 3 May 2020.

CEN and CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN and CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN and CENELEC members are the national standards bodies and national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels

Table of contents

European Foreword	9
1 Scope	10
2 Normative references	11
3 Terms, definitions and abbreviated terms	13
3.1 Terms defined in other standards	13
3.2 Terms specific to the present standard	13
3.3 Abbreviated terms	26
3.4 Conventions	29
3.4.1 Numbers	29
3.4.2 Multiplication	29
3.4.3 Differential signals	29
3.4.4 Order of sending bits in symbols	29
3.4.5 Graphical representation of packets	30
3.4.6 State diagram notation	30
3.4.7 UML diagram notation	31
3.4.8 D/K notation for 8B/10B characters	32
3.5 Nomenclature	32
4 Principles	34
4.1 SpaceFibre purpose	34
4.2 SpaceFibre overview	35
5 Requirements	37
5.1 Overview	37
5.2 Protocol stack and interface architecture	37
5.2.1 General	37
5.2.2 Network layer	39
5.2.3 Data Link layer	39
5.2.4 Multi-Lane layer	40
5.2.5 Lane layer	40
5.2.6 Physical layer	41

5.2.7	Management Information Base	41
5.3	Formats	41
5.3.1	Control words and encoding/decoding	41
5.3.2	8B/10B encode/decode	42
5.3.3	Lane control words	44
5.3.4	Multi-Lane control words	51
5.3.5	Data Link control words	53
5.3.6	Receive error indication control word (RXERR)	62
5.3.7	Characters	63
5.3.8	Frames	66
5.3.9	Packets	70
5.3.10	Control word and frame precedence	70
5.3.11	K-code summary	73
5.3.12	Control word symbol summary	73
5.4	Physical layer	74
5.4.1	Physical layer responsibilities	74
5.4.2	Serialisation	75
5.4.3	Electrical physical layer	77
5.4.4	Electrical medium	88
5.4.5	Fibre optic physical layer	97
5.4.6	Fibre optic medium	103
5.5	Lane layer	112
5.5.1	Lane layer responsibilities	112
5.5.2	Lane initialisation and standby management	114
5.5.3	Data signalling rate compensation	126
5.5.4	IDLE words	126
5.5.5	Parallel loopback	127
5.5.6	Symbol synchronisation	127
5.5.7	Word synchronisation	127
5.5.8	Receive synchronisation state machine	129
5.6	Multi-Lane layer	131
5.6.1	Multi-Lane layer responsibilities	131
5.6.2	Multi-Lane link	132
5.6.3	Multi-Lane bypass	133
5.6.4	Multi-Lane distribution	133
5.6.5	Multi-Lane concentration	137
5.6.6	Lane Alignment	137

5.6.7	Alignment state diagram	141
5.6.8	Asymmetric links	144
5.6.9	Initialisation of unidirectional lanes	145
5.6.10	Hot redundant lanes	146
5.7	Data Link layer	149
5.7.1	Data Link layer responsibilities	149
5.7.2	Virtual channels	151
5.7.3	Flow control	153
5.7.4	Medium access controller	155
5.7.5	Broadcast flow control	163
5.7.6	Framing	164
5.7.7	Error recovery	177
5.7.8	Data word identification state machine	184
5.7.9	Link Reset state machine	189
5.7.10	Link reset	192
5.8	Network layer	194
5.8.1	Network layer responsibilities	194
5.8.2	SpaceFibre network	195
5.8.3	Virtual networks	196
5.8.4	Links	199
5.8.5	Packet format	199
5.8.6	Sending a packet	200
5.8.7	Receiving a packet	200
5.8.8	Routing switch	201
5.8.9	Packet addressing	207
5.8.10	Group adaptive routing	209
5.8.11	Packet multicast	209
5.8.12	Broadcast messages	210
5.8.13	SpaceFibre nodes	212
5.8.14	SpaceFibre units	213
5.9	Management Information Base	214
5.9.1	Management Information Base responsibilities	214
5.9.2	Network management	214
5.9.3	Configuration parameters	215
5.9.4	Status parameters	219
6	Service interfaces	221
6.1	Overview	221

6.2	Network layer service interface	221
6.2.1	Network layer services	221
6.2.2	Packet Transfer service	221
6.2.3	Broadcast message service	223
6.3	Data Link layer service interface	224
6.3.1	Data Link layer services	224
6.3.2	Virtual Channel service	224
6.3.3	Broadcast message service	225
6.3.4	Schedule synchronisation service	226
6.4	Physical layer service interfaces	227
6.4.1	Physical layer services	227
6.4.2	Transfer symbols service	227
6.4.3	Control service	228
6.5	Management Information Base service interface	230
6.5.1	Management Information Base services	230
6.5.2	Link Management service	230
Bibliography.....		232

Figures

Figure 3-1: Convention for first bit to be sent	29
Figure 3-2: Graphical packet notation	30
Figure 3-3: State diagram style	30
Figure 3-4: UML notation	31
Figure 3-5: D/K notation for 8B/10B characters	32
Figure 4-1: Overview of SpaceFibre protocol stack	35
Figure 5-1: SpaceFibre protocol stack - single-lane	38
Figure 5-2: SpaceFibre protocol stack - multi-lane	39
Figure 5-3: Fills at the end of packets	65
Figure 5-4: Fills at the start and end of a packet	66
Figure 5-5: Data frame format for a single lane	66
Figure 5-6: Idle frame format	67
Figure 5-7: Broadcast frame format	68
Figure 5-8: Interfaces to the Physical layer	75
Figure 5-9: One direction of electrical Physical layer, showing series capacitors, discharge resistors, and different grounds	77
Figure 5-10: Serial output signals	79
Figure 5-11: Serial output test circuit	80

Figure 5-12: Serial eye pattern mask.....	80
Figure 5-13: Serial input signals	86
Figure 5-14: Type-A electrical flight cable assembly	89
Figure 5-15: Type-A electrical flight connector saver	90
Figure 5-16: Type-C electrical EGSE cable assembly	93
Figure 5-17: Type-C electrical EGSE to flight adaptor cable assembly	94
Figure 5-18: One direction of fibre optic Physical layer, showing fibre optic transmitter, receiver, connectors and cable.....	97
Figure 5-19: One direction of active optical cable type of fibre optic Physical layer.....	97
Figure 5-20: Electro-optical eye pattern for 1 Gbit/s to 5 Gbit/s transmitters	99
Figure 5-21: Electro-optical eye pattern for 1 Gbit/s to 10 Gbit/s transmitters	100
Figure 5-22: SpaceFibre lane comprising two Type-A fibre optic flight cable assemblies, one for each direction.....	105
Figure 5-23: Type-B fibre optic flight cable assembly with one lane.....	107
Figure 5-24: Type-B fibre optic flight cable assembly with several lanes	108
Figure 5-25: Type-B fibre optic flight cable assembly for an asymmetric link	108
Figure 5-26: Type-C flight active optical cable assembly	111
Figure 5-27: Interfaces to the Lane layer for a single lane link	113
Figure 5-28: Interfaces to the Lane layer for a multi-lane link.....	114
Figure 5-29: Lane initialisation state machine.....	115
Figure 5-30: Receive synchronisation state machine.....	129
Figure 5-31: Interfaces to Multi-Lane layer	132
Figure 5-32: Multi-Lane link with different number of lanes at each end	133
Figure 5-33: Words forming a row across a multi-lane link	134
Figure 5-34: Spreading data across a multi-lane link	135
Figure 5-35: PAD control words in a multi-lane link	135
Figure 5-36: Row alignment across a multi-lane link.....	140
Figure 5-37: Alignment state machine	141
Figure 5-38: Multi-Lane link incorporating some unidirectional lanes	144
Figure 5-39: Interfaces to the Data Link layer for a single lane link.....	150
Figure 5-40: Interfaces to the Data Link layer for a multi-lane link	150
Figure 5-41: Scrambler / de-scrambler	165
Figure 5-42: Example of scrambling of a short data frame.....	166
Figure 5-43: Effect of scrambling on an idle frame.....	167
Figure 5-44: Examples of CRC calculation for a short data frame	172
Figure 5-45: Illustration of bit ordering during 16-bit CRC calculation	172
Figure 5-46: Examples of CRC calculation for a broadcast frame and FCT	175
Figure 5-47: Illustration of bit ordering during 8-bit CRC calculation	176

Figure 5-48: Receive Error state machine	182
Figure 5-49: Data Word Identification state machine	185
Figure 5-50: Link Reset state machine	190
Figure 5-51: Interfaces to the Network layer	194
Figure 5-52: Components of a SpaceFibre network.....	195
Figure 5-53: Relationships of a SpaceFibre virtual network	197
Figure 5-54: SpaceFibre packet format	199
Figure 5-55: Components of a SpaceFibre routing switch	202
Figure 5-56: Components and specialisations of a SpaceFibre node	212
Figure 5-57: Components and specialisations of a SpaceFibre unit	214

Tables

Table 5-1: 5B/6B encoding	43
Table 5-2: 3B/4B encoding	44
Table 5-3: Lane control words	44
Table 5-4: Multi-Lane control words.....	51
Table 5-5: Data framing control words.....	53
Table 5-6: Flow control word	58
Table 5-7: Error recovery control words.....	60
Table 5-8: Receive error indication control word.....	63
Table 5-9: SpaceFibre N-Char Symbols	64
Table 5-10: Fill control character symbol	64
Table 5-11: Meaning of K-codes.....	73
Table 5-12: Meaning of control word symbols	73
Table 5-13: Serial output interface.....	77
Table 5-14: Serial eye pattern mask intervals 1 Gbit/s to 3,125 Gbit/s.....	81
Table 5-15: Serial eye pattern mask intervals above 3,125 Gbit/s to 6,25 Gbit/s	81
Table 5-16: Coefficient α for different values of BER	82
Table 5-17: Driver and receiver characteristics 1 Gbit/s to 3,125 Gbit/s.....	83
Table 5-18: Driver and receiver characteristics above 3,125 Gbit/s to 6,25 Gbit/s	84
Table 5-19: Serial input interface	85
Table 5-20: Type-A electrical flight cable assembly connector contact terminations	89
Table 5-21: Type-A electrical flight connector saver connector contact terminations	89
Table 5-22: Type-B electrical flight cable assembly connector contact terminations	92
Table 5-23: Type-C electrical EGSE cable assembly connector contact terminations	93
Table 5-24: Type-C electrical EGSE to flight adaptor cable assembly connector contact terminations	94
Table 5-25: Type-D electrical EGSE cable assembly connector contact terminations	96

Table 5-26: Electro-optical characteristics for 1 Gbit/s to 5 Gbit/s transmitters	100
Table 5-27: Electro-optical characteristics for 1 Gbit/s to 10 Gbit/s transmitters	101
Table 5-28: Electro-optical characteristics for 1 Gbit/s to 5 Gbit/s receivers.....	102
Table 5-29: Electro-optical characteristics for 1 Gbit/s to 10 Gbit/s receivers.....	103
Table 5-30: Connection of SpaceFibre lane using Type-A flight fibre optic cable assemblies	105
Table 5-31: Type-B flight fibre optic cable assembly connector contact terminations for each SpaceFibre lane	107
Table 5-32: Type-C flight active optical cable connector terminations for each SpaceFibre lane	109
Table 5-33: Type-C flight active optical cable assembly connector contact terminations for each SpaceFibre lane	110
Table 5-34: Precedence for different qualities of service	158
Table 5-35: Routing switch addresses	204
Table 5-36: SpaceFibre configuration parameters	216
Table 5-37: SpaceFibre status parameters.....	219

European Foreword

This document (EN 16603-50-11:2020) has been prepared by Technical Committee CEN-CENELEC/TC 5 "Space", the secretariat of which is held by DIN.

This document (EN 16603-50-11:2020) originates from ECSS-E-ST-50-11C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2021, and conflicting national standards shall be withdrawn at the latest by March 2021.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1

Scope

SpaceFibre is a very high-speed serial link and network technology, designed specifically for use on board spacecraft. SpaceFibre is able to operate over fibre-optic and electrical cable and supports data rates of up to 5 Gbit/s (6,25 Gbit/s data signalling rate). It complements the capabilities of the widely used SpaceWire on-board networking standard: improving the data rate by a factor of 10, reducing the cable mass and providing galvanic isolation. Multi-laning improves the data rate further to well over 20 Gbit/s.

SpaceFibre provides a coherent quality of service mechanism able to support bandwidth reserved, scheduled and priority-based qualities of service. It substantially improves the fault detection, isolation and recovery (FDIR) capability compared to SpaceWire.

SpaceFibre aims to support high data-rate payloads, for example synthetic aperture radar and hyper-spectral optical instruments. It provides robust, long distance communications for launcher applications and supports avionics applications with deterministic delivery constraints through the use of virtual channels. SpaceFibre enables a common on-board infrastructure to be used across many different mission applications resulting in cost reduction and design reusability. SpaceFibre uses a packet format which is the same as SpaceWire enabling simple connection between existing SpaceWire equipment and high-speed SpaceFibre links and networks. Applications developed for SpaceWire can be readily transferred to SpaceFibre.

The SpaceFibre standard specifies the interfaces to the user application and to the physical medium. Intermediate interfaces between protocol layers are also specified. The functions that a SpaceFibre interface has to implement are specified. Connector and cable characteristics for SpaceFibre optical and copper implementations are also specified.

This standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system - Glossary of terms
EN 16603-50-52	ECSS-E-ST-50-52	Space engineering - SpaceWire – Remote memory access protocol
EN 16602-70-02	ECSS-Q-ST-70-02	Space product assurance - Thermal vacuum outgassing test for the screening of space materials
EN 16602-70-21	ECSS-Q-ST-70-21	Space product assurance - Flammability testing for the screening of space materials
EN 16602-70-29	ECSS-Q-ST-70-29	Space product assurance - Determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment
	ESCC 2263420:2017	Evaluation Test programme for optical fibre cable assemblies, ESCC Basic Specification, issue 1, June 2017
	ESCC 3401/090:2018	High Data Rate Connectors Savers, Plugs based on type AxoMach, ESCC Detail Specification, issue 1, 2018
	ESCC 3409:2018	High Data Rate Cable Assemblies, ESCC Generic Specification, issue 1, 2018
	ESCC 3409/001:2018	High Data Rate Harnesses based on type AxoMach, ESCC Detail Specification, issue 1, 2018
	ESCC 3420:2017	Optical Fibre Cable Assemblies with Single Fibre Ferrules, ESCC Generic Specification, issue 1, June 2017
	ESCC 3420/001:2017	Optical Fibre Cable Assemblies with Single Fibre Ferrules, ESCC Detail Specification, issue 1, June 2017

EN reference	Reference in text	Title
	IEC 60793-2-10:2015	Optical fibres - Part 2-10: Product specifications - Sectional specification for category A1 multimode fibres, IEC, 2015
	IEC 61754-5:2005	Fibre optic connector interfaces - Part 5: Type MT connector family, IEC, 2005
	IEC 61755-3-31:2015	Fibre optic interconnecting devices and passive components - Connector optical interfaces - Part 3-31: Connector parameters of non-dispersion shifted single mode physically contacting fibres - Angled polyphenylene sulphide rectangular ferrules
	IEC 61755-3-32:2015	Fibre optic interconnecting devices and passive components - Connector optical interfaces - Part 3-32: Connector parameters of non-dispersion shifted single mode physically contacting fibres - Angled thermoset epoxy rectangular ferrules
	IEEE 802.3:2012	IEEE Standard for Ethernet, IEEE Standards Association, 28 December 2012
	MIL-PRF-49291, Revision D, Amendment 1, 20 November 2014	Performance Specification, Fiber, Optical, (Metric) General Specification
	Serial ATA Revision 3.0:2009	Serial ATA Revision 3.0, clause 6.6.1, Serial ATA International Organization, June 2, 2009, Gold Revision

Terms, definitions and abbreviated terms

3.1 Terms defined in other standards

- a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 active lane

unidirectional lane or **bi-directional lane** which is in the Active state

3.2.2 asymmetric link

multi-lane link that includes one or more **unidirectional lanes**

3.2.3 available bandwidth

number of **data words** or **control words** sent since the **bandwidth credit** was last updated

3.2.4 bandwidth credit

amount of **link bandwidth** that a **virtual channel** has accumulated

3.2.5 bandwidth credit limit

maximum amount of positive or negative **bandwidth credit** that a **virtual channel** is allowed to accumulate

3.2.6 bandwidth utilisation

measure of how much bandwidth allocated to a **virtual channel** has been used recently, allowing for loss of measured use of bandwidth when either the positive or negative **bandwidth credit limit** is reached

3.2.7 bi-directional lane

active lane or **inactive lane** which has the TX_EN and RX_EN configuration bits asserted at both ends of the **link**, so that when active it can send information in both directions of the **link**

3.2.8 bit error rate

ratio of the number of bits received in error to the total number of bits sent across a **link**

3.2.9 bit interval

duration of a bit travelling over a serial interface

3.2.10 broadcast frame

broadcast message which has been encapsulated using an SBF at the front of the **broadcast message** and an EBF at the end of the **broadcast message**

3.2.11 broadcast message

eight bytes of application data sent to every **node** on the **network**, along with an eight-bit broadcast type, which determines the meaning of the application data

3.2.12 byte

eight bits

3.2.13 cargo

information for transferring from a **source** to a **destination** which is encapsulated in a **packet**

3.2.14 character

data character or **control character**

3.2.15 coding

act of translating a set of bits into another set of bits which are more appropriate for transmitting across a medium

3.2.16 comma

K28.5 or K28.7 **control symbol**

3.2.17 configuration port

port in a **routing switch** or **node** that gives access to a **configuration node**

3.2.18 configuration node

type of **node** whose purpose is to configure the **routing switch** that it is part of

3.2.19 continuous mode

mode of **virtual channel** operation which ignores flow control so that data can always be accepted from the Network layer but if the **virtual channel** buffer is full that data will be discarded

3.2.20 control character

character containing 8-bits of control information

3.2.21 control symbol

K-symbol

3.2.22 control word

word used for control of the SpaceFibre protocol comprising a **comma**, or the K-code of an EBF, EDF, FCT or RXERR, followed by three **data characters** or **Fills**

3.2.23 current running disparity

accumulated disparity of a bit stream from when it started to the present moment in time

3.2.24 data character

character containing 8-bits of data information

3.2.25 data frame

segment of N-Chars and Fills from one or more packets which have been encapsulated using an SDF, for each lane, at the front of the segment and an EDF, for each lane, at the end of that segment

3.2.26 Data Link layer

protocol layer which is responsible for transferring **packets** and **broadcast messages** over the **link**, for the quality of service over the **link**, and for recovery from errors on the **link**

3.2.27 Data Link layer control word

ACK, NACK, FULL, RETRY, SDF, EDF, SBF, EBF, SIF, or FCT **control word**

3.2.28 data rate

rate at which the application data is transferred across a **link**

3.2.29 data-receiving lane

active, receive enabled **lane**, which is connected to a **data-sending lane** so that it can receive **Data Link layer words**

NOTE Receive enabled lane means RX_EN asserted at the near-end of the **link**.

3.2.30 data segment

group of up to N×64 sequential **data words** from one or more **packets**, where N is an integer less than or equal to the "maximum number of data-sending lanes" parameter

NOTE The term "segment" is synonymous.

3.2.31 data-sending lane

active, transmit enabled **lane** which when provided with **Data Link layer words**, sends them to the **data-receiving lane** at the far-end of the **link**

NOTE Transmit enabled lane means TX_EN asserted at the near-end of the **link**.

3.2.32 data signalling rate

rate at which the bits constituting control and data **symbols** are transferred across a link

3.2.33 data symbol

D-symbol

3.2.34 data word

word of data comprising four SpaceFibre **N-Chars** or **Fill** characters

3.2.35 decoding

act of translating an encoded set of bits back into the original set of bits prior to encoding

3.2.36 device

node or routing switch

3.2.37 de-serialisation

transformation of a serial bit stream into parallel data

3.2.38 deserialiser

circuit that converts a sequence of bits from a serial bit stream into parallel data

3.2.39 destination

end-point that a **packet** is being sent to

3.2.40 destination address

route to be taken by a **packet** in moving from **source** to **destination** or an identifier specifying the **destination**

3.2.41 destination node

node that is the **destination** of one or more SpaceFibre **packets**

3.2.42 disparity

number of ones in a bit stream minus the number of zeros in that bit stream

3.2.43 driver

electronic circuit that transmits signals across a particular **transmission medium**

3.2.44 D-code

9-bit representation of an 8-bit **data character** which is transmitted using 8B/10B encoding comprising a **D/K flag**, which is set to zero, and the 8-bit **data character**

3.2.45 D-symbol

10-bit **symbol** formed by 8B/10B encoding of a **D-code**

3.2.46 D/K flag

1-bit flag forming part of a **D-code** or **K-code**, which when set to zero indicates the code is a **D-code** or when set to one, is a **K-code**

3.2.47 end of packet marker (EOP)

N-Char which indicates the end of a **packet**

3.2.48 end-point

interface between the **network** and a **host system** providing a single **port** into the **network**

3.2.49 error end of packet marker (EEP)

N-Char which indicates the end of a **packet** in which an error has occurred

3.2.50 FarEndActive

indication that the far-end of a lane is in the Active state, the indication being sent in an ACTIVE control word over any **lane** forming part of a **multi-lane link**

3.2.51 Fill

character used in a PAD control word or used for word alignment which can occur in a **data frame** between the end of one packet and the beginning of the next one, or after reset, before the beginning of the first packet

3.2.52 flow control token (FCT)

control word used to manage the flow of data across a **link** and which is exchanged for $M \times 64$ data words, where M is an integer in the range 1 to 8

3.2.53 frame

data frame, **broadcast frame** or **idle frame**

3.2.54 header deletion

removal of the leading **data character** of a **packet** by a **routing switch** after it has been used to determine the **output port** that the **packet** is forwarded to and before the **packet** is switched to that **output port**, that **leading data character** being replaced by a **Fill**

3.2.55 host interface

interface to a **host system**

3.2.56 host system

system that is connected to a SpaceFibre **network** via an **end-point** and which uses the services of that SpaceFibre **network**

3.2.57 hot redundant lane

active, transmit enabled **lane**, which is not a **data-sending lane** and which is ready to replace a failed **data-sending lane**

NOTE Transmit enabled lane means TX_EN asserted at the near-end of the **link**.

3.2.58 idle frame

frame of pseudo-random data which is sent when there are no **data frames** or **broadcast frames** to be sent

3.2.59 inactive lane

unidirectional lane or bi-directional lane which is NOT in the Active state

3.2.60 Initialisation comma

K28.5 control symbol

3.2.61 input port

receive side of a **port**

3.2.62 invalid symbol

symbol that does not occur in the 8B/10B decoding table

NOTE That is not a valid **symbol** for a **D-code** or **K-code**.

3.2.63 jitter

deviation from true periodicity of a nominally periodic signal

3.2.64 K-code

9-bit representation of an 8-bit **control character** which is transmitted using 8B/10B encoding comprising a **D/K flag**, which is set to one, and an 8-bit **control character** set to one of 12 possible valid values

3.2.65 K-symbol

10-bit **symbol** formed by 8B/10B encoding of a **K-code**

3.2.66 lane

SpaceFibre physical connection between two **devices**

3.2.67 Lane layer control word

SKIP, IDLE, INIT1, iINIT1, INIT2, iINIT2, INIT3, STANDBY or LOST_SIGNAL **control word**

3.2.68 LaneReset

reset of the Lane layer of a SpaceFibre **link**, without resetting the Data Link layer

3.2.69 LaneStart

management parameter set by hardware or software which when asserted causes the SpaceFibre **lane** to start initialisation by sending INIT1s

3.2.70 leading data character

very first **data character** sent over a **link** or the first **data character** following the EOP or EEP that terminated the previous SpaceFibre **packet**

3.2.71 line

medium between a **driver** and a **receiver**

3.2.72 line driver

electronic circuit that drives signals across a particular **transmission medium**

3.2.73 line receiver

electronic circuit that receives signals sent across a particular **transmission medium**

3.2.74 link

bi-directional connection between two **ports**, that incorporates one or more **lanes**, used to transfer **packets** and **broadcast messages** between the two **ports**

3.2.75 link bandwidth

number of **data words** and **control words** that can be sent over a SpaceFibre **link** in one second

3.2.76 link reset

reset of the Data Link and lower layers of a SpaceFibre **link**

3.2.77 logical address

data character which identifies the **destination** for the **packet**

3.2.78 management parameter

configuration parameter, control parameter or status value of a SpaceFibre **node** or **routing switch** used to manage its operation

3.2.79 Multi-Lane layer control word

ACTIVE or ALIGN **control word**

3.2.80 multi-lane link

link comprising two or more **lanes**

3.2.81 N-Char

SpaceFibre **data character**, EOP or EEP

3.2.82 negative bandwidth credit limit

minimum value of **bandwidth credit** that a **virtual channel** is allowed to drop to

3.2.83 negative disparity

more zeros than ones in a bit stream

3.2.84 network

two or more **nodes** connected together via one or more **links** and zero or more **routing switches**

3.2.85 network manager

node that configures, controls and monitors the status of the SpaceFibre **network**

3.2.86 neutral disparity

same number of ones and zeros in a bit stream

3.2.87 node

source or **destination** of SpaceFibre **packets** and **broadcast messages** comprising one or more **end-points**, each providing an interface between a **port** and a **host system**

3.2.88 normalised expected bandwidth

link bandwidth that a **virtual channel** is expected to use as a proportion of the overall **link bandwidth**

3.2.89 NoSignal

signal indicating that the input at the receiver is below the level needed for correct operation

3.2.90 output port

transmit side of a **port**

3.2.91 packet

sequence of N-Chars comprising a **destination address**, **cargo** and an **end of packet marker**

3.2.92 PAD

control word, comprising a K28.7 **comma** followed by three **Fills**, used in a **multi-lane link** for padding unused **words** in a **row**

3.2.93 parallel interface

interface which transfers several bits simultaneously

3.2.94 path address

series of one or more **data characters** at the start of a **packet** which define the route to be taken across a SpaceFibre **network** from **source** to **destination**

3.2.95 permanent error

error on a **lane** that cannot be recovered

3.2.96 persistent error

error on a **lane** that can be recovered only by re-initialising the faulty **lane** and resending the data

3.2.97 Physical layer

protocol layer which specifies the cables, connectors, cable assemblies, **line drivers**, **line receivers**, **serialisation** and **de-serialisation**

3.2.98 point to point link

link connecting two **nodes**

3.2.99 port

SpaceFibre interface or parallel interface comprising an **input port** and an **output port**

3.2.100 port of arrival

port on which a **packet** or **broadcast message** arrives

3.2.101 positive bandwidth credit limit

maximum value of **bandwidth credit** that a **virtual channel** is allowed to reach

3.2.102 positive disparity

more ones than zeros in a bit stream

3.2.103 previous port of arrival

port on which a **broadcast message** arrived before the current **broadcast message** arrived in the same **broadcast channel**

3.2.104 priority precedence

static precedence value of a **virtual channel** derived from the setting of the priority quality of service **management parameter** for that **virtual channel**

3.2.105 ready virtual channel

virtual channel with data ready to send and space in the input **virtual channel** buffer at the far-end of the **link**

3.2.106 receive error indication control word

control word, RXERR, generated by the Lane layer when it detects an error in the information received over the SpaceFibre **link** and passed to the Data Link layer to indicate that an error has occurred

3.2.107 receive only lane

active lane or **inactive lane** which has the TX_EN configuration bit de-asserted and the RX_EN bit asserted at the near-end of the **link**, thus forming the receive end of a **unidirectional lane**

3.2.108 receiver

receiving end of a SpaceFibre **lane** or **link**

3.2.109 receiving row

set of words that is received in parallel from all data-receiving lanes at approximately the same time, i.e. within the time it takes to receive one **word** by one **lane**, which is the bit period times 40

3.2.110 reserved bandwidth

portion of **link bandwidth** that is set aside for use by a specific **virtual channel**

3.2.111 reset

power on reset, other hardware reset or software commanded reset

3.2.112 return loss

$10\log_{10}(P_i/P_r) = -10\log_{10}(P_r/P_i) = -20 \log_{10}(V_r/V_i)$ where P_i is the incident power, P_r is the reflected power, V_i the incident voltage and V_r the reflected voltage, and which has a positive value when the reflected signal is less than the incident signal

3.2.113 router

see “**routing switch**”

3.2.114 routing switch

device comprising several **SpaceFibre ports** and a **switch matrix** that switches **packets** arriving on one **port** out of another **port** according to the **destination address** of the **packet** and the contents of a **routing table**, that validates and broadcasts **broadcast messages** out of all of the **ports** except the one on which the **broadcast message** arrived, and which includes a **configuration port** for configuring the **ports** and the **routing switch** itself

NOTE The term “router” is synonymous.

3.2.115 routing table

table in a **routing switch** that is used to look-up the **output port** for sending a **packet** through, using the **leading data character** of the **packet** as an index into that table

3.2.116 row

sending row or receiving row

3.2.117 schedule

list of **time-slots** during which a **virtual channel** is permitted to send **data frames**

3.2.118 segment

see “**data segment**”

3.2.119 sending row

set of **words** that is sent in parallel by all **data-sending lanes** at approximately the same time,

NOTE The same time means within the time it takes to transmit one **word**

3.2.120 serialisation

transformation of a sequence of control or data **symbols** into a serial bit stream

3.2.121 serialiser

circuit that converts parallel data into a sequence of bits in a serial bit stream

3.2.122 signal

measurable quantity that varies with time and propagates along a **transmission medium** to transfer information across that medium

3.2.123 skew

difference in time between the expected position of the rising or falling edge of a signal and the actual position of that signal

3.2.124 source

originator of a **packet**, signal or other form of information

3.2.125 source node

node that is the **source** of one or more SpaceFibre **packets**

3.2.126 SpaceFibre interface

interface able to send information across a SpaceFibre **link**, and receive information from that SpaceFibre **link**

3.2.127 SpaceFibre port

port which has a SpaceFibre interface

3.2.128 switch matrix

non-blocking switch that passes a **packet** arriving at an **input port** of a **routing switch** to the appropriate **output port**

3.2.129 symbol

D-symbol or K-symbol

3.2.130 symbol rate

rate at which **symbols** can be handled in the **transmitter** and **receiver**

3.2.131 symbol word

group of four consecutive **symbols** that when decoded forms a **data word** or **control word**

3.2.132 time-slot

identified interval of time used for scheduling the transmission of **data frames**

3.2.133 transient error

error on a **link** that can be recovered from by resending the data without re-initialising the **link**

3.2.134 transmission medium

medium over which data is transferred

NOTE For example screened twisted-pair wires

3.2.135 transmit only lane

active lane or **inactive lane** which has the TX_EN configuration bit asserted and the RX_EN configuration bit de-asserted at the near-end of the **link**, thus forming the transmit end of a **unidirectional lane**

3.2.136 transmitter

sending end of a SpaceFibre **lane** or **link**

3.2.137 transmitting lane

active lane or **inactive lane** which has the TX_EN configuration bit asserted at the near-end of the **link** and which can operate as a **data-sending lane** or **hot redundant lane**

3.2.138 unidirectional lane

lane that sends information in one direction only

3.2.139 unit

entity, which contains zero or more **nodes** and zero or more **routing switches** and which contains at least one **node** or one **routing switch**

NOTE Instrument processor and mass memory are examples of an entity.

3.2.140 unrecognised symbol

symbol that does not appear in the 8B/10B **symbol** table

3.2.141 used bandwidth

amount of data, sent by a particular **virtual channel** in the last **data frame**, which is zero for all **virtual channels** except the one that sent the last **data frame**

3.2.142 valid symbol

symbol that does not produce a **disparity** error and is found in the 8B/10B decoding table

3.2.143 virtual channel

independent channel that can carry information across a single link in parallel with other independent, information carrying channels

3.2.144 virtual network

logical network that runs in parallel with other logical networks over a single physical network

3.2.145 word

data word or control word

3.3 Abbreviated terms

The following abbreviations are defined and used within this standard:

Abbreviation	Meaning
8B/10B	8-bit/10-bit
AC	alternating current
ACK	acknowledgement
ACT_LS	active least significant
ACT_MS	active most significant
ACTIVE	active control word
ALIGN	align control word
ASIC	application specific integrated circuit
ATA	advance technology attachment
AVIM	aviation intermediate maintenance
B_TYPE	broadcast type
BC	broadcast channel
BER	bit error rate
CDR	clock data recovery
CML	current mode logic
COMMA	comma K28.7
CRC	cyclic redundancy code
DC	direct current
D/K	data/control
DMA	direct memory access
EBF	end of broadcast frame
EDF	end of data frame
EEP	error end of packet
EGSE	electronic ground support equipment
EM	electro-magnetic
EMI	electro-magnetic interference
EOP	end of packet
ER	extinction ratio
FCT	flow control token
FDIR	fault detection, isolation and recovery
FIFO	first in first out
FPGA	field programmable gate array
FULL	full control word
Gbit/s	giga bits per second
GND	ground

Abbreviation	Meaning
I2C	inter-integrated circuit
IDLE	idle control word
iINIT1	inverse initialisation control word 1
iINIT2	inverse initialisation control word 2
iLANES	inverse lane field
iLLCW	inverse Lane layer control word
INIT1	initialisation control word 1
INIT2	initialisation control word 2
INIT3	initialisation control word 3
ITU	International Telecommunication Union
LANE	lane field
LFSR	linear feedback shift register
LLCW	Lane layer control word
LoS	loss of signal indication
LOS	loss of signal
LOST_SIGNAL	lost signal control word
LS	least-significant
LSB	least-significant bit
LVC MOS	low voltage complementary metal oxide semiconductor
LVDS	low voltage differential signalling
LVPECL	low voltage positive emitter coupled logic
LVTTL	low voltage transistor – transistor logic
MS	most-significant
MT	mechanically transferable
NACK	negative acknowledgement
N-Char	normal character
NO SIG	NoSignal
OM	optical multimode
OMA	optical modulation amplitude
OSI	Open Systems Interconnection
PAD	pad control word
PCB	printed circuit board
PD	photo detector
PIN	p-type semiconductor, intrinsic semiconductor, n-type semiconductor
PLL	phase locked loop

Abbreviation	Meaning
PRBS	pseudo-random bit sequence
QoS	quality of service
RC	resistor - capacitor
RETRY	retry control word
RIN	relative intensity noise
RMAP	remote memory access protocol
RX	receive
RX_EN	receive enable
RXERR	receive error control word
SBF	start of broadcast frame
SDF	start of data frame
SEQ_NUM	sequence number
SerDes	serialiser-deserialiser
SIF	start of idle frame
SKIP	skip control word
SMA	sub-miniature version A
STANDBY	standby control word
STATUS	status field
TX	transmit
TX_EN	transmit enable
UI	unit interval
UML	universal modelling language
VC	virtual channel
VCB	virtual channel buffer
VCSEL	vertical cavity surface emitting laser
V _{DIFF}	voltage differential
V _{DIFF-PK}	voltage differential peak
V _{DIFF-PK-PK}	voltage differential peak to peak
VML	voltage mode logic
VN	virtual network
XOR	exclusive OR

3.4 Conventions

3.4.1 Numbers

In this document hexadecimal numbers are written with the prefix 0x, for example 0x34 and 0xDF15.

Binary numbers are written with the prefix 0b, for example 0b01001100 and 0b01.

Decimal numbers have no prefix.

A comma is used as a decimal point.

3.4.2 Multiplication

The symbol $\times$ is used to indicate multiplication. For example, $N \times 64$ means N times 64.

3.4.3 Differential signals

The two signals making up a differential pair are given the suffixes + and – to indicate the positive and negative components of the differential signal, respectively.

3.4.4 Order of sending bits in symbols

The bits of a 10-bit symbol are sent least significant bit first.

The four symbols of a symbol word are sent least significant symbol first.

An arrow is added to relevant diagrams to illustrate the direction that the data moves and which bit is sent first, as shown in Figure 3-1.

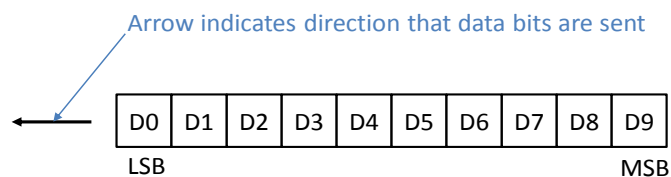


Figure 3-1: Convention for first bit to be sent

3.4.5 Graphical representation of packets

Packets and their component fields are represented graphically as shown in Figure 3-2. The arrow indicates the direction that the packet is travelling, so the destination address field is sent first.

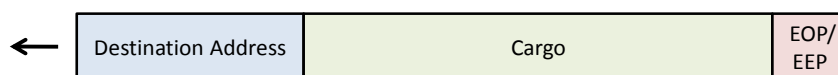


Figure 3-2: Graphical packet notation

3.4.6 State diagram notation

State diagrams are used to represent the behaviour of several parts of the SpaceFibre protocol. All state diagrams in this Standard use the style shown in Figure 3-3. States are represented by ellipses with the state name written inside the ellipse in bold. Actions to take while in a particular state are written in italics inside the ellipse underneath the state name. Transitions from one state to another are indicated by arrows. The event that causes a transition is written alongside the arrow. Unconditional transitions are indicated by arrows without an event name written next to them. Reset conditions are indicated by transition arrows that start in empty space.

A condition in a state relates to that state only, unless there is a specific statement to the contrary. For example, the condition “When three INIT3 control words are received” expressed in a particular state, means three INIT3 control words being received while in that state.

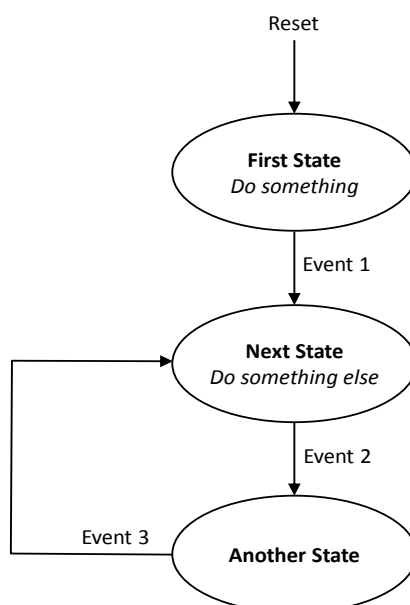


Figure 3-3: State diagram style

3.4.7 UML diagram notation

UML diagrams in this document use the notation illustrated in Figure 3-4.

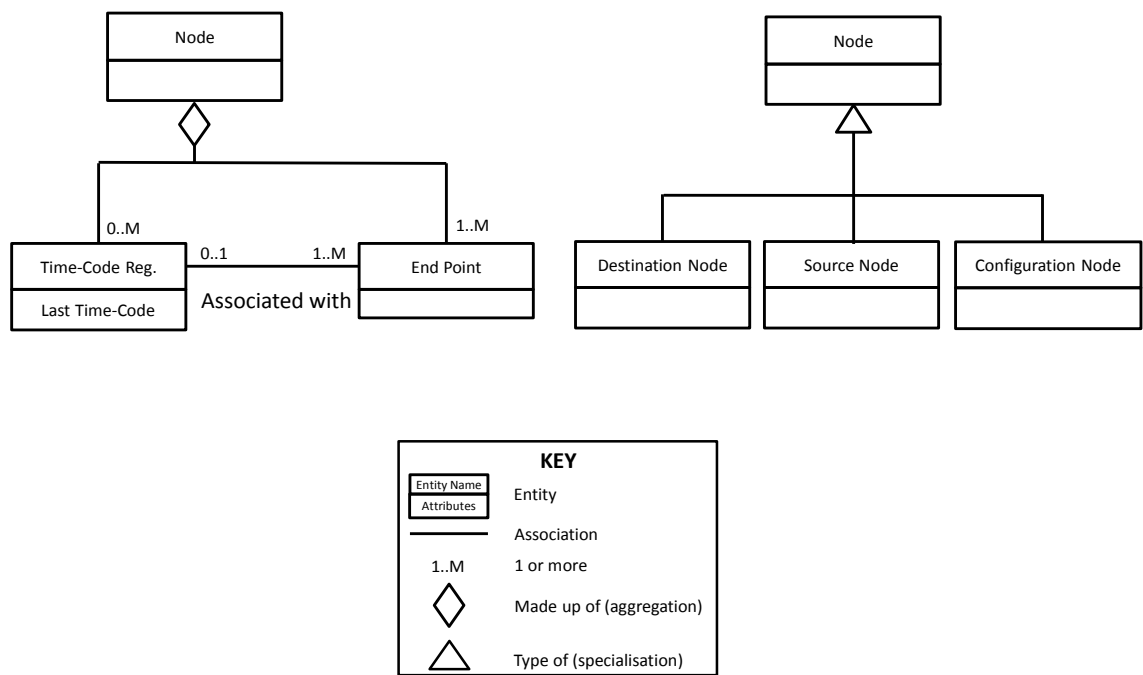


Figure 3-4: UML notation

Each entity (or object) is shown as a rectangle divided in two by a horizontal line. The name of the entity is at the top above the line and a list of key attributes is below the line. Only those attributes that are particularly relevant to understanding a diagram are shown, for example “Last Time-Code” in the Time-Code Register.

A diamond is used to represent aggregation and is translated as “is made up of”, hence in Figure 3-4 a node is made up of one or more (1..M) end-points and zero or more (0..M) time-code registers. The number at the end of the line shows the cardinality of the relationship and is either a number (e.g. 1) or a range (e.g. 1..M) with M representing more or many.

A triangle represents generalisation in one direction (reading in the direction the triangle is pointing) and specialisation in the other. So, in Figure 3-4, a destination node is a special type of node. Reading in the other direction, a node is a generalisation of destination node, source node and configuration node.

Other associations between entities are shown as lines connecting the two objects. A name capturing the intent of the association is written alongside the line. If the association is general, no name needs to be given to it. Hence, in Figure 3-4, each end-point is associated with zero or more time-code registers and each time-code register is associated with 1 or more end-points.

3.4.8 D/K notation for 8B/10B characters

The 8B/10B encoding scheme uses a particular type of notation for describing data and control characters. A data character is in the format D/xx.y where xx is the decimal representation of the least significant 5 bits of the data byte being sent and y is the decimal representation of the most significant three bits of the data byte being sent. Similarly, a control character is represented by K/xx.y. This is illustrated in Figure 3-5 along with two examples.

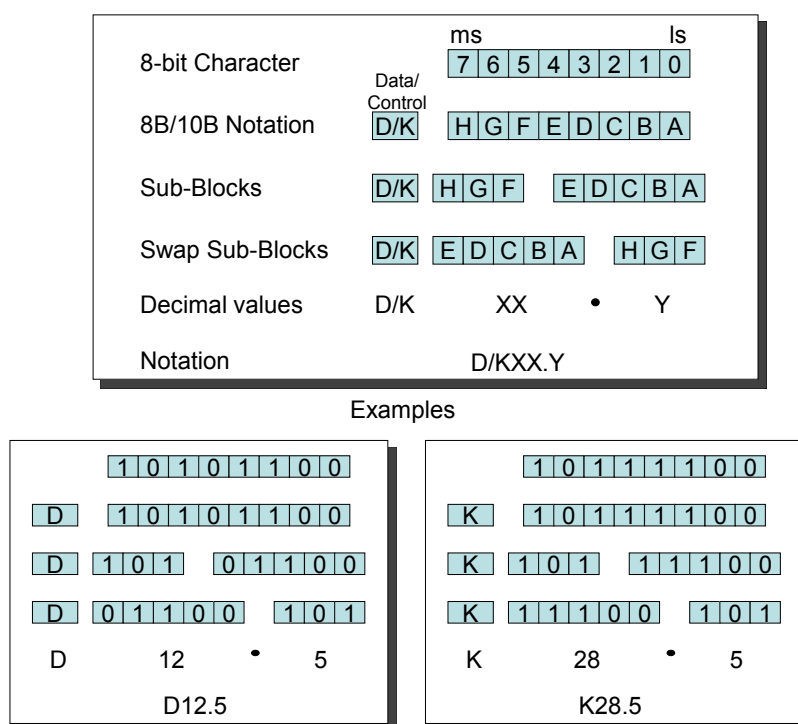


Figure 3-5: D/K notation for 8B/10B characters

3.5 Nomenclature

The following nomenclature applies throughout this document:

- The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

- The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

- e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

4

Principles

4.1 SpaceFibre purpose

SpaceFibre is a multi-Gigabit/s data link and network technology specifically designed for spaceflight applications including high data-rate payload data-handling such as synthetic aperture radar (SAR), multi-spectral imaging systems and fast mass-memory units. SpaceFibre data links are full-duplex and run over either electrical or fibre-optic media. SpaceFibre includes built-in, very efficient, quality of service (QoS) and fault detection, isolation and recovery (FDIR) techniques, which simplify the use of SpaceFibre enormously; providing substantial system level benefits without requiring the implementation of complex, performance limiting, software protocols.

SpaceFibre is backwards compatible with SpaceWire (ECSS-E-ST-50-12) at the packet level allowing easy bridging between SpaceWire and SpaceFibre, so that existing SpaceWire devices can be incorporated into a SpaceFibre network and take advantage of its performance, and QoS and FDIR capabilities. SpaceFibre provides robust, long distance communications for launcher applications and supports avionics applications with deterministic delivery constraints. SpaceFibre enables a common on-board network technology to be used across many different mission applications resulting in cost reduction and design reusability. SpaceFibre performs the following:

- Supports high data rate payloads,
- Carries data from existing SpaceWire instruments,
- Performs low latency time-distribution,
- Provides low latency event signalling,
- Provides deterministic data delivery to support guidance and navigation control applications,
- Supports any network topology.

4.2 SpaceFibre overview

An overview of the SpaceFibre protocol stack is provided in Figure 4-1.

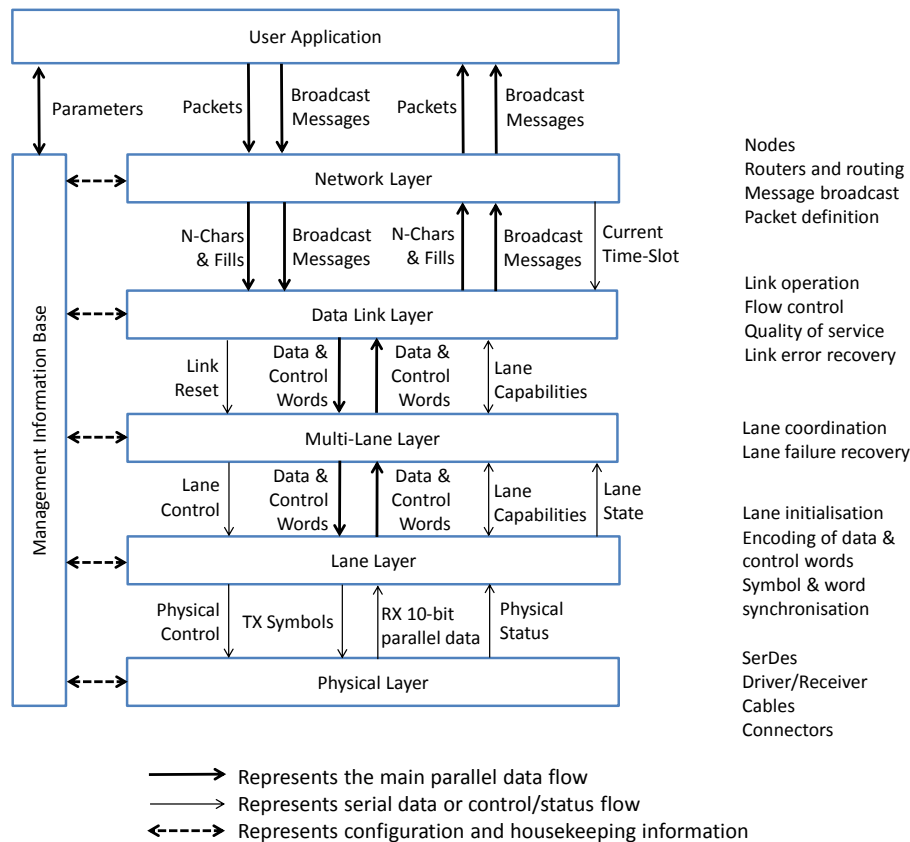


Figure 4-1: Overview of SpaceFibre protocol stack

There are five conceptual layers to the SpaceFibre protocol: Network layer, Data Link layer, Multi-Lane layer, Lane layer and Physical layer.

The Network layer is responsible for the transfer of application information over a SpaceFibre network. It provides two services: Packet Transfer service and Broadcast Message service. The Packet Transfer service transfers SpaceFibre packets over the SpaceFibre network, using the same packet format and routing concepts as SpaceWire uses. SpaceFibre supports both path and logical addressing. The Broadcast Message service is responsible for broadcasting short messages (8 bytes) to all nodes on the network. These messages can carry time and synchronisation signals and be used to signal the occurrence of various events on the network.

The Data Link layer is responsible for providing quality of service (QoS) and managing the flow of information over a SpaceFibre link, using one or more virtual channels with independent flow control. It frames the information to be sent over the link to support QoS and optionally scrambles the packet data to reduce electromagnetic emissions. The Data Link layer is also responsible for error recovery, by resending frames and control words that have been detected by the far-end of a link as erroneous or missing. SpaceFibre is very resilient to transient errors.

The Multi-Lane layer is responsible for operating several SpaceFibre lanes in parallel to provide higher data throughput. In the event of a lane failing the Multi-Lane layer provides support for graceful degradation, automatically spreading the traffic over the remaining working lanes. A SpaceFibre link is the logical data link, which can comprise one or more physical lanes. The use of multiple lanes is optional.

The Lane layer is responsible for establishing communications across a SpaceFibre lane, for encoding data and control words into symbols, for sending and receiving symbols over the lane, for decoding the received symbols into data and control words, and for re-establishing communications across the lane when an error occurs on a lane. 8B/10B encoding is used which provides a DC balanced signal that can be AC coupled to provide galvanic isolation.

The Physical layer is, on the transmitter side, responsible for serialising the 8B/10B symbols and for sending them over the physical medium. On the receiver side, the Physical layer is responsible for recovering the clock and data from the serial bit stream. Both electrical cables and fibre-optic cables are supported by SpaceFibre.

The Management Information Base is responsible for configuring, controlling and monitoring the status of all the layers in the SpaceFibre protocol stack.

The service interface specifications for each OSI layer within the SpaceFibre protocol stack are provided in clause 6.

The connectors, cable and cable assemblies specified in the Physical layer are divided into several types. For example, for the electrical medium, the following types are specified:

- Type-A connectors, cables and cable assemblies are specific, fully specified parts for flight use.
- Type-B provides a generic specification of the electrical properties needed allowing a range of different flight capable solutions to be implemented.
- Type-C are specific, fully defined parts for electronic ground support applications.
- Type-D provides a generic specification of the electrical properties for electronic ground support cables.

Type-A and Type-C are for immediate use, Type-B and Type-D allow for innovation and more capable solutions to be developed in future.

5

Requirements

5.1 Overview

Clause 5 provides the normative requirements for SpaceFibre. It is separated into the following functional layers.

- Clause 5.2 specifies the SpaceFibre protocol stack and conceptual architecture of a SpaceFibre port.
- Clause 5.3 specifies the formats of the control words, characters, frames and packets used by SpaceFibre.
- Clause 5.4 specifies the Physical layer which covers the specification of the serialiser, deserialiser, line drivers, line receivers, connectors, cables, and cable assemblies.
- Clause 5.5 specifies the Lane layer which performs lane initialisation, encoding of characters into symbols, receive symbol and word synchronisation, decoding of symbols into characters, and compensation for differences in clocking speeds at the two ends of the lane.
- Clause 5.6 specifies the Multi-Lane layer which supports several lanes operating together to provide a single link of higher bandwidth than a single lane.
- Clause 5.7 specifies the Data Link layer which provides link quality of service (QoS) and fault detection, isolation and recovery (FDIR).
- Clause 5.8 specifies the network layer which covers SpaceFibre packets, nodes, routing switches, networks and broadcast messages.
- Clause 5.9 specifies the Management Information Base.

5.2 Protocol stack and interface architecture

5.2.1 General

- a. The SpaceFibre protocol stack shall have a Network layer, Data Link layer, Multi-Lane layer, Lane layer, Physical layer and Management Information Base.

NOTE 1 The SpaceFibre protocol stack is illustrated in Figure 5-1 for a single lane and in Figure 5-2 for a multi-lane link. The service interfaces for each

layer of the SpaceFibre protocol stack are specified in clause 6.

NOTE 2 From the perspective of the layers of the OSI Model, the Lane layer and the Multi-Lane layer are sublayers of the Data Link layer. The Data Link, Multi-Lane and Lane layers form one layer from the implementation perspective. The separation into layers has been done to group related functionalities together for ease of understanding.

- b. The Multi-Lane layer may be omitted, when only a single lane is being used.

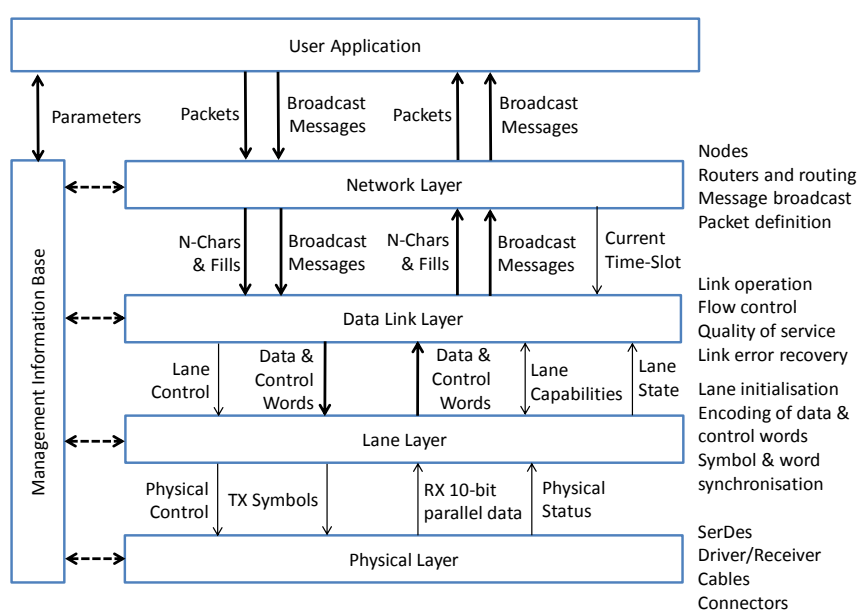


Figure 5-1: SpaceFibre protocol stack - single-lane

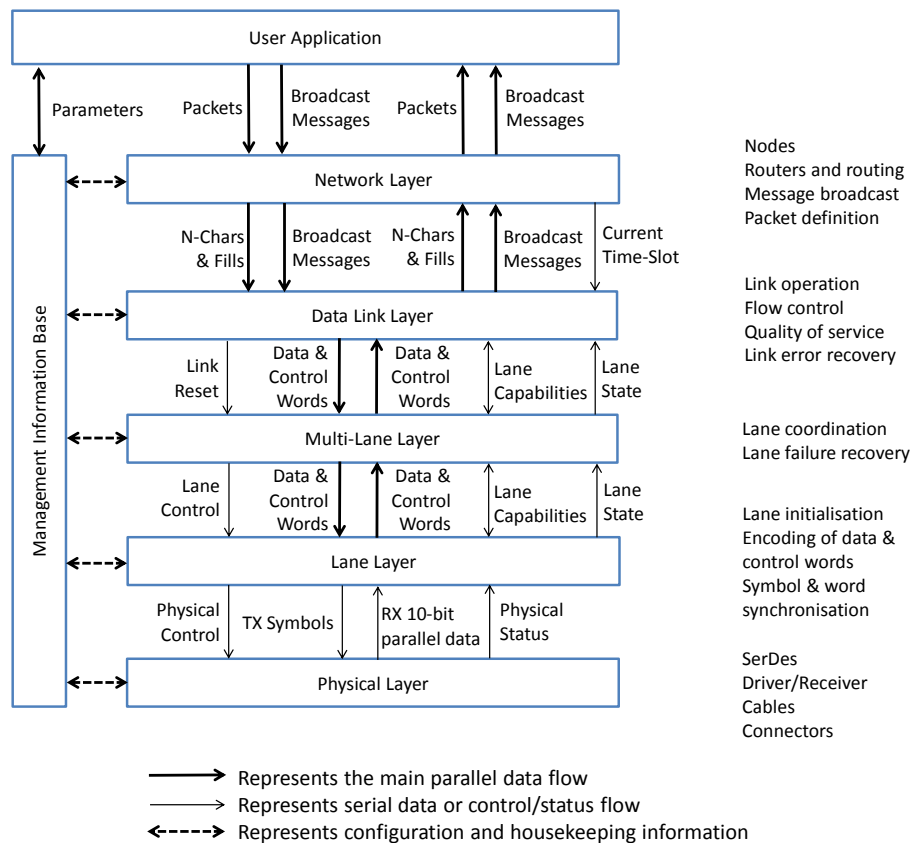


Figure 5-2: SpaceFibre protocol stack - multi-lane

5.2.2 Network layer

- a. The SpaceFibre Network layer shall provide two principal services:
 1. A Packet Transfer service which sends and receives packets over a SpaceFibre network.
 2. A Broadcast Message service which sends and receives broadcast messages over a SpaceFibre network.
- b. A SpaceFibre implementation shall support the Packet Transfer service and the Broadcast Message service.
- c. The SpaceFibre Network layer shall accept service requests from user applications.
- d. The SpaceFibre Network layer shall use the services of the SpaceFibre Data Link layer.

5.2.3 Data Link layer

- a. The SpaceFibre Data Link layer shall provide three services:
 1. A Virtual Channel service, supporting multiple virtual channels with independent flow control, which sends and receives N-Chars and Fills, the components of packets, over a SpaceFibre link.

2. A Broadcast service which sends and receives broadcast messages over a SpaceFibre link.
 3. A Schedule Synchronisation service which receives current time-slot information in order to synchronise the scheduled QoS.
- b. The Data Link layer shall accept service requests from the Network layer.
 - c. The Data Link layer shall use the services of the SpaceFibre Multi-Lane or Lane layer.

5.2.4 Multi-Lane layer

- a. The SpaceFibre Multi-Lane layer is an optional layer which shall provide three services:
 1. A Transfer Word service which sends data and control words over a SpaceFibre link and which receives data and control words over a SpaceFibre link.
 2. A Link Reset service which resets all the lanes of a link.
 3. A Capabilities service which sets the capabilities of each lane at the near-end of a link and reports the capabilities of each lane at the far-end of the link.
- b. The Multi-Lane layer shall accept service requests from the Data Link layer.
- c. The Multi-Lane layer shall use the services of the SpaceFibre Lane layer.

5.2.5 Lane layer

- a. The SpaceFibre Lane layer shall provide three services:
 1. A Transfer Word service which sends data and control words over a SpaceFibre lane and which receives data and control words over a SpaceFibre link.
 2. A Control service which controls the operation of the lanes in a link, using the TxOnly, RxOnly, FarEndActive, and LaneReset signals for each lane and which provides the current state of the Lane Initialisation state machine.
 3. A Capabilities service which sets the capabilities of each lane at the near-end of a link and reports the capabilities of each lane at the far-end of the link.
- b. The Lane layer shall accept service requests from the SpaceFibre Data Link layer or Multi-Lane layer.
- c. The Lane layer shall use the services of the SpaceFibre Physical layer.

5.2.6 Physical layer

- a. The SpaceFibre Physical layer shall provide two services:
 - 1. A Transfer Symbol service which serialises the symbols provided by the Lane layer and transmits them over the physical medium, and which receives the data signal from the physical medium, de-serialises it to produce 10-bit parallel data and passes it to the Lane layer.
 - 2. A Control service which controls the operation of the line driver, line receiver and SerDes and which reports the status of the line receiver and SerDes.
- b. The SpaceFibre Physical layer shall accept service requests from the Lane layer.

5.2.7 Management Information Base

- a. The SpaceFibre Management Information Base shall provide one service:
 - 1. A Management service which writes control or configuration information to all SpaceFibre layers and which reads the status or current configuration or control values of all SpaceFibre layers.
- b. The SpaceFibre Management Information Base shall accept service requests from a user application.
- c. The SpaceFibre Management Information Base shall have direct access to the relevant configuration parameters, control parameters and status parameters in the Network layer, Data Link layer, Multi-Lane layer, Lane layer and Physical layer.

5.3 Formats

5.3.1 Control words and encoding/decoding

- a. Several types of control words shall be used by SpaceFibre:
 - 1. Lane control words.
 - 2. Multi-Lane control words.
 - 3. Data Link control words.
 - 4. Receive error indication control word, which is generated in the receiver and is not sent over the SpaceFibre link.
- b. SpaceFibre shall encode/decode information to send over a lane using 8B/10B encoding/decoding.

5.3.2 8B/10B encode/decode

- a. The SpaceFibre port shall use 8B/10B encoding to encode each 8-bit data character or control character into a 10-bit symbol that is transmitted.
- b. To ensure DC balancing of the transmitted signal, account shall be kept of the current running disparity in the transmitter.
- c. When an 8-bit data character or control character is being encoded and the current running disparity is positive, the symbol for that data character or control character which has negative or neutral disparity shall be used.
- d. When an 8-bit data character or control character is being encoded and the current running disparity is negative, the symbol for that data character or control character which has positive or neutral disparity shall be used.
- e. Upon reset the current running disparity shall be set to plus one or minus one.
- f. To detect disparity errors, account shall be kept of the current running disparity in the receiver.
- g. If the current running disparity is more than plus one or less than minus one, the receiver shall indicate a disparity error.
- h. When a disparity error occurs, the current running disparity in the receiver shall be set to plus one if it was greater than plus one and to minus one if it was less than minus one.
- i. When a symbol is received, it shall be decoded into an 8-bit data character or control character using the 8B/10B symbol table.
- j. The 8B/10B encoder shall encode the least-significant five-bits of a data character or control character as specified in Table 5-1 and the most significant three bits as specified in Table 5-2.

Table 5-1: 5B/6B encoding

Input		Output	
Data Input	Data bits 43210 EDCBA	Current Running Disparity -ve abcdei	Current Running Disparity +ve abcdei
D00.y	00000	100111	011000
D01.y	00001	011101	100010
D02.y	00010	101101	010010
D03.y	00011	110001	
D04.y	00100	110101	001010
D05.y	00101	101001	
D06.y	00110	011001	
D07.y	00111	111000	000111
D08.y	01000	111001	000110
D09.y	01001	100101	
D10.y	01010	010101	
D11.y	01011	110100	
D12.y	01100	001101	
D13.y	01101	101100	
D14.y	01110	011100	
D15.y	01111	010111	101000
D16.y	10000	011011	100100
D17.y	10001	100011	
D18.y	10010	010011	
D19.y	10011	110010	
D20.y	10100	001011	
D21.y	10101	101010	
D22.y	10110	011010	
D/K23.y	10111	111010	000101
D24.y	11000	110011	001100
D25.y	11001	100110	
D26.y	11010	010110	
D/K27.y	11011	110110	001001
D28.y	11100	001110	
K28.y	11100	001111	110000
D/K29.y	11101	101110	010001
D/K30.y	11110	011110	100001
D31.y	11111	101011	010100

Table 5-2: 3B/4B encoding

Input		Output	
Data Input	Data bits 765 HGF	5B/6B Disparity -ve fghj	5B/6B Disparity +ve fghj
D/Kxx.0	000	1011	0100
Dxx.1	001	1001	
Kxx.1	001	0110	1001
Dxx.2	010	0101	
Kxx.2	010	1010	0101
D/Kxx.3	011	1100	0011
D/Kxx.4	100	1101	0010
Dxx.5	101	1010	
Kxx.5	101	0101	1010
Dxx.6	110	0110	
Kxx.6	110	1001	0110
Dxx.7	111	1110/0111	0001/1000
Kxx.7	111	0111	1000

5.3.3 Lane control words

5.3.3.1 General

- a. The lane control words shall be used to initialise a SpaceFibre lane, to indicate loss of signal, and to indicate that a lane is about to go into standby.

NOTE The lane control words are constructed as shown in Table 5-3.

Table 5-3: Lane control words

Name	Control word	Function
SKIP	Comma, LLCW, SKIP, SKIP K28.7, D14.6, D31.3, D31.3	Sent every 5000 control words or data words to support the receiver elastic buffer operation.
IDLE	Comma, LLCW, IDLE, IDLE K28.7, D14.6, D15.6, D15.6	Sent when the link is initialised and the Data Link or Multi-Lane layer does not provide valid words to be sent.
INIT1	Init Comma, LLCW, INIT1, INIT1 K28.5, D14.6, D6.2, D6.2	Sent as part of the initialisation handshake. D6.2 has neutral disparity.

Name	Control word	Function
inverse INIT1	Init Comma, iLLCW, iINIT1, iINIT1 K28.5, D17.1, D25.5, D25.5	Received as part of the initialisation handshake if the Physical layer signals are inverted. D25.5 has neutral disparity.
INIT2	Init Comma, LLCW, INIT2, INIT2 K28.5, D14.6, D6.5, D6.5	Sent as part of the initialisation handshake. D6.5 has neutral disparity.
inverse INIT2	Init Comma, iLLCW, iINIT2, iINIT2 K28.5, D17.1, D25.2, D25.2	Received as part of the initialisation handshake if the Physical layer signals are inverted. D25.5 has neutral disparity.
INIT3	Init Comma, LLCW, INIT3, Capability K28.5, D14.6, D24.1, D0.0-D31.7	Sent as part of the initialisation handshake. The Capability field describes the capability of the end of the lane sending the INIT3. This can be used to exchange information about the capability of the SpaceFibre interface at the other end of the lane, so that the two ends of the lane can operate in the most efficient way possible.
STANDBY	Comma, LLCW, STBY, Reason K28.7, D14.6, D30.3, D0.0-D31.7	Indicates that the transmitter is moving to the Standby state and about to tri-state its driver. This can be used to save power when the host has no data to transmit and no data is currently being received. The Standby Reason field can be used to indicate the reason why the STANDBY control word was sent or provide other status information.
LOST_SIGNAL	Comma, LLCW, LOS, Reason K28.7, D14.6, D4.3, D0.0-D2.0	Indicates that the end of the link sending the LOST_SIGNAL control word has lost signal on its receiver. The Reason field is used to indicate the cause of the NoSignal.

5.3.3.2 SKIP control word

- The SKIP control word shall begin with a comma, K28.7, which is in the least significant symbol position of the control word and is sent first.
- The second symbol in the SKIP control word shall be the Lane Layer Control Word, LLCW, identifier, which has the value D14.6 and identifies the control word as being a control word generated and used by the Lane layer.

- c. The third symbol in the SKIP control word shall identify the Lane layer control word as being a SKIP control word, and has the value D31.3.
- d. The fourth and final symbol in the SKIP control word shall be a copy of the third symbol.

NOTE The SKIP control word is used to support operation of the data signalling rate compensation in the SpaceFibre receiver, see 5.5.3.

5.3.3.3 IDLE control word

- a. The IDLE control word shall begin with a comma, K28.7, which is in the least significant symbol position of the control word and is sent first.
- b. The second symbol in the IDLE control word shall be the Lane Layer Control Word, LLCW, identifier, which has the value D14.6 and identifies the control word as being a control word generated and used by the Lane layer.
- c. The third symbol in the IDLE control word shall identify the Lane Layer Control Word as being an IDLE control word, and has the value D15.6.
- d. The fourth and final symbol in the IDLE control word shall be a copy of the third symbol.

NOTE The IDLE control word is sent, after initialisation, to keep the lane running when there is no other information to send.

5.3.3.4 INIT1 control word

- a. The INIT1 control word, used during lane initialisation, shall begin with an initialisation comma, K28.5, which is in the least significant symbol position of the control word and is sent first.
- b. The second symbol in the INIT1 control word shall be the Lane Layer Control Word, LLCW, identifier, which has the value D14.6 and identifies the control word as being a control word generated and used by the Lane layer.
- c. The third symbol in the INIT1 control word shall identify the Lane Layer Control Word as being an INIT1 control word, and has the value D6.2.
- d. The fourth and final symbol in the INIT1 control word shall be a copy of the third symbol.

5.3.3.5 Inverse INIT1 control word

- a. The Inverse INIT1 control word, iINIT1, shall begin with an initialisation comma, K28.5, which is in the least significant symbol position of the control word and is received first.
- b. The second symbol in the Inverse INIT1 control word shall be the Inverse Lane Layer Control Word, iLLCW, identifier, which has the value D17.1 and identifies the control word as being a control word generated and used by the Lane layer.

- c. The third symbol in the Inverse INIT1 control word shall identify the Lane Layer Control Word as being an Inverse INIT1 control word, and has the value D25.5.
- d. The fourth and final symbol in the Inverse INIT1 control word shall be a copy of the third symbol.
- e. The Inverse INIT1 control word shall not be generated by the SpaceFibre port.

NOTE The Inverse INIT1 is formed when the PCB layout in a SpaceFibre transmitter or receiver crosses over the two signals, CML+ and CML-, making up the differential signal.

5.3.3.6 INIT2 control word

- a. The INIT2 control word, used during lane initialisation, shall begin with an initialisation comma, K28.5, which is in the least significant symbol position of the control word and is sent first.
- b. The second symbol in the INIT2 control word shall be the Lane Layer Control Word, LLCW, identifier, which has the value D14.6 and identifies the control word as being a control word generated and used by the Lane layer.
- c. The third symbol in the INIT2 control word shall identify the Lane Layer Control Word as being an INIT2 control word, and has the value D6.5.
- d. The fourth and final symbol in the INIT2 control word shall be a copy of the third symbol.

5.3.3.7 Inverse INIT2 control word

- a. The Inverse INIT2 control word, iINIT2, shall begin with an initialisation comma, K28.5, which is in the least significant symbol position of the control word and is received first.
- b. The second symbol in the Inverse INIT2 control word shall be the Inverse Lane Layer Control Word, iLLCW, identifier, which has the value D17.1 and identifies the control word as being a control word generated and used by the Lane layer.
- c. The third symbol in the Inverse INIT2 control word shall identify the Lane Layer Control Word as being an Inverse INIT2 control word, and has the value D25.2.
- d. The fourth and final symbol in the Inverse INIT2 control word shall be a copy of the third symbol.
- e. The Inverse INIT2 control word shall not be generated by the SpaceFibre port.

NOTE The Inverse INIT2 is formed when the PCB layout in a SpaceFibre transmitter or receiver crosses over the two signals, CML+ and CML-, making up the differential signal.

5.3.3.8 INIT3 control word

- a. The INIT3 control word, used during lane initialisation, shall begin with an initialisation comma, K28.5, which is in the least significant symbol position of the control word and is sent first.
- b. The second symbol in the INIT3 control word shall be the Lane Layer Control Word, LLCW, identifier, which has the value D14.6 and identifies the control word as being a control word generated and used by the Lane layer.
- c. The third symbol in the INIT3 control word, which has the value D24.1, shall identify the Lane Layer Control Word as being an INIT3 control word.
- d. The fourth and final symbol in the INIT3 control word, Capability, shall be a data symbol with any value from D0.0 to D31.7 and encode a data character containing control flags and information about the capability of the lane.

NOTE It is not necessary for the Capability field to have valid inverse symbols, since by the time INIT3s are being sent any necessary receiver inversion is already completed.

- e. The Capability data character shall contain several fields as follows:
 1. Bit 0: the INIT3LinkResetFlag.
 2. Bit 1: the INIT3LaneStart flag.
 3. Bit 2: the INIT3DataScrambled flag.
 4. Bit 3: the INIT3Multi-LaneCapable flag.
 5. Bit 4: the INIT3RoutingSwitch flag.
 6. Bits 5 to 7: reserved, which are set to zero when transmitted and ignored when received.
- f. The INIT3LinkResetFlag shall take on one of the following values:
 1. INIT3LinkResetFlag=0, which means that at least one lane of the SpaceFibre port sending the INIT3 control word has been in the Active state at least once since the last link reset or power on reset.
 2. INIT3LinkResetFlag=1, which means that the SpaceFibre port sending the INIT3 control word has not had any lane in the Active state since the last link reset or power on reset.

NOTE The reset values of various parameters are specified in clause 5.9.

- g. The INIT3LaneStart flag shall take on one of the following values:
 1. INIT3LaneStart=0, which means that the SpaceFibre lane sending the INIT3 control word has its LaneStart management parameter NOT set.
 2. INIT3LaneStart=1, which means that the SpaceFibre lane sending the INIT3 control word has its LaneStart management parameter set.