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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – General

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Recommendation ITU-T G.709.3/Y.1331.3

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Recommendation ITU-T G.709.3/Y.1331.3

Flexible OTN long-reach interfaces

Summary

Recommendation ITU-T G.709.3/Y.1331.3 defines the flexible optical transport network (OTN), known as FlexO, long-reach interfaces that support bonding (i.e. grouping) of multiple of these interfaces such that an OTUCn ($n \geq 1$) can be transferred via one or more optical tributary signals (OTSi) over one or more physical interfaces. The Recommendation specifies the frame structure for FlexO long reach interfaces using forward error correction codes with a higher coding gain than used in the FlexO short reach interfaces that are specified in Recommendation ITU-T G.709.1/Y.1331.1.

NOTE – In this first edition only a 100G FlexO long reach interface is specified. Other FlexO long reach interface specifications are for further study.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.709.3/Y.1331.3	2018-06-22	15	11.1002/1000/13523

Keywords

FlexO, FEC, long reach, OTN.

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* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Flexible OTN long-reach interfaces

1 Scope

This Recommendation defines the flexible optical transport network (OTN), known as FlexO, long-reach interfaces that support bonding (i.e. grouping) of multiple of these interfaces such that an OTUCn ($n \geq 1$) can be transferred via one or more optical tributary signals (OTSi) over one or more physical interfaces.

The optical parameters associated with FlexO long reach interfaces are provided by application codes, which will be in a future edition of [ITU-T G.698.2].

A FlexO long reach interface group complements the OTN functionality specified in [ITU-T G.709] and [ITU-T G.709.1] such as B100G OTUCn frame, ODUk/flex, optical interface bonding for short reach interfaces, FlexO interface group management and OTUCn (de)mapping into/from FlexO group payload area, with new functionalities supporting optical interface bonding for long reach interfaces.

This Recommendation provides specifications for new functionalities that are specific to FlexO long reach interface groups and refers to [ITU-T G.709], [ITU-T G.709.1], [ITU-T G.709.2] and [ITU-T G.798] for already existing functionalities. In addition, some introduction material for the addressed applications is included.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.698.2] Recommendation ITU-T G.698.2 (2009), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces.*

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2016), *Interfaces for the optical transport network.*

[ITU-T G.709.1] Recommendation ITU-T G.709.1/Y.1331.1 (2017), *Flexible OTN short-reach interface*.

[ITU-T G.709.2] Recommendation ITU-T G.709.2/Y.1331.2 (2018), *OTU4 long-reach interface.*

[ITU-T G.798] Recommendation ITU-T G.798 (2017), *Characteristics of optical transport network hierarchy equipment functional blocks.*

[ITU-T G.872] Recommendation ITU-T G.872 (2017), *Architecture of optical transport networks.*

[ITU-T G.975.1] Recommendation ITU-T G.975.1 (2004), *Forward error correction for high bit-rate DWDM submarine systems*.

[IEEE 802.3] IEEE Std. 802.3-2015, *IEEE Standard for Information Technology – Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area Networks – Specific Requirements Part 3: Carrier Sense Multiple Access With Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 Terms defined in [ITU-T G.709]

– completely standardized OTUCn (OTUCn)

– optical data unit (ODUCn)

– optical payload unit (OPUCn)

– optical transport network (OTN)

– optical data unit k (ODUk)

– optical tributary signal assembly (OTSiA)

3.1.2 Terms defined in [ITU-T G.709.1]

– FlexO

– FlexO-x

– FlexO-x-RS

– FlexO-x-RS interface

– FlexO-x-RS-m interface group

– FOICx.k-RS

– FOICx.k-RS lane.

3.1.3 Terms defined in [ITU-T G.709.2]

– Base block

3.1.4 Terms defined in [ITU-T G.975.1]

– coding gain

– net coding gain.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 FEC Block Group (FBG): Refers to a group of 1,305,430 contiguous bits in consecutive FlexO-x-SC rows which maps to five base blocks.

3.2.2 FlexO-x-SC: Information structure consisting of a FlexO-x plus staircase FEC parity and overhead.

3.2.3 FlexO-x-SC interface: Refers to an individual member interface that is part of a FlexO-x-SC-m interface group.

3.2.4 FlexO-x-SC-m interface group: Refers to the group of m × FlexO-x-SC interfaces.

NOTE – The text may use "FlexO group" as short-hand for FlexO-x-SC-m interface group.

3.2.5 FOICx.k-SC: Refers to a FlexO-x-SC interface using k parallel FOICx.k-SC lanes.

NOTE – "FOICx.k" is the FlexO equivalent of "OTLk.m" for OTUk as defined in [ITU-T G.709].

3.2.6 FOICx.k-SC lane: Refers to an electrical/optical lane of a FlexO-x-SC.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AM	Alignment Marker
B100G	Beyond 100G
BCH	Bose-Chaudhuri-Hocquengham
DWDM	Dense Wavelength Division Multiplex
ED	Error Decorrelator
EDI	Error Decorrelator Interleaver
EDD	Error Decorrelator De-interleaver
FBA	FEC Block Alignment
FBG	FEC Block Group
FEC	Forward Error Correction
FlexO	Flexible OTN information structure
FlexO-x	FlexO interface information structure of order x
FlexO-x-SC	FlexO interface signal of order x with staircase FEC
FOI	FlexO Interface
FOICx.k	FlexO Interface of order Cx with k lanes
LR	Long Reach
MBAS	Multi Block Alignment Signal
MLD	Multi-Lane Distribution
MOTU	Multi-OTU
MOTUm	Multi-OTU with management
NCG	Net Coding Gain
NNI	Network Node Interface
OCC	Overhead Communication Channel
ODU	Optical Data Unit
ODU*k*	ODU order *k*
ODU*Cn*	ODU order *Cn*
OSMC	OTN Synchronization Messaging Channel
OTN	Optical Transport Network
OTSi	Optical Tributary Signal

OTU	Optical Transport Unit
SC FEC	Staircase FEC
SOTU	Single OTU
SOTUm	Single-OTU with Management
RS	Reed Solomon

5 Conventions

This Recommendation uses the following conventions:

k: The index "k" is used to represent a supported bit rate and the different versions of OPUk, ODUk and OTUk. Example for k are "1" for an approximate bit rate of 2.5 Gbit/s, "2" for an approximate bit rate of 10 Gbit/s, and "3" for an approximate bit rate of 40 Gbit/s.

Cn: The index Cn is used for n × 100G (C = 100G).

m: The index "m" is used to represent the bit rate or set of bit rates supported on the interface. This is one or more digits "k", where each "k" represents a particular bit rate. For example, valid values for m are (1, 2, 3, 12, 123, 23).

n: The index "n" is used to represent the order of the OTM, OTS, OMS, OPS, OCG, OMU. n represents the maximum number of wavelengths that can be supported at the lowest bit rate supported on the wavelength. It is possible that a reduced number of higher bit rate wavelengths are supported. n = 0 represents the case of a single channel without a specific colour assigned to the channel.

Transmission order: The order of transmission of information in all the diagrams in this Recommendation is first from left to right and then from top to bottom. Within each byte the most significant bit is transmitted first. The most significant bit (bit 1) is illustrated at the left in all the diagrams.

Value of reserved bit(s): The value of an overhead bit, which is reserved or reserved for future international standardization, shall be set to "0".

Value of non-sourced bit(s): Unless stated otherwise, any non-sourced bits shall be set to "0".

6 Introduction and applications

The FlexO long reach interface groups specified in this Recommendation provide a longer reach version of the FlexO short reach interface groups specified in [ITU-T G.709.1]. In order to mitigate the impairments of accumulated noise it uses forward error correction (FEC) types with a higher coding gain than the FEC type deployed in FlexO short reach interfaces.

Example applications are shown in Appendix I.

This Recommendation specifies FlexO-x-<fec>-m interface groups, of which x ≥ 1, m ≥ 1 and <fec> represents a FEC with a net coding gain higher than the RS(544,514) FEC in FlexO-x-RS-m interface groups specified in [ITU-T G.709.1].

Edition 1.0 of this Recommendation specifies the (m × 100G) FlexO-1-SC-m interface group, with m = n.

NOTE – The FOIC*x*.*k*-SC specified in this Recommendation is not envisaged to be reused on a system internal interface (i.e., a module framer interface), instead such interfaces can deploy the FOIC*x*.*k* as specified in [b-ITU-T G-Sup.58].

7 Structure and processes

This clause introduces the functions associated with a FlexO-x-SC-m interface group and the basic signal structure, processes and atomic functions.

7.1 FlexO-x-SC-m signal structure

The FlexO-x-SC-m interface group in this Recommendation is only specified for long-reach applications. For short reach applications, refer to [ITU-T G.709.1]. The FlexO-x-SC-m interface group functional model is specified in [ITU-T G.872].

NOTE – The physical optical interface specifications are beyond the scope of this Recommendation.

The information structure for FlexO-x-SC-m interface groups is represented by information containment relationships and information flows. The principal information containment relationship is shown in Figure 7-1.

One OTUCn signal (consisting of n OTUC instances) is mapped into the payload of n FlexO signals, each FlexO signal containing the bits of one OTUC signal. The n FlexO signals are mapped into m ($m = \lceil n/x \rceil$) FlexO-x-SC signals, each FlexO-x-SC signal containing "x" (frame/multi-frame aligned interleaved) FlexO signals ($x \geq 1$) plus FEC parity and FlexO-x-SC overhead. Each FlexO-x-SC signal is split into k FlexO-x-SC lane signals (FOIC*x*.*k*-SC). The k lane signals are modulated onto one OTSi, which is transported via one media element.

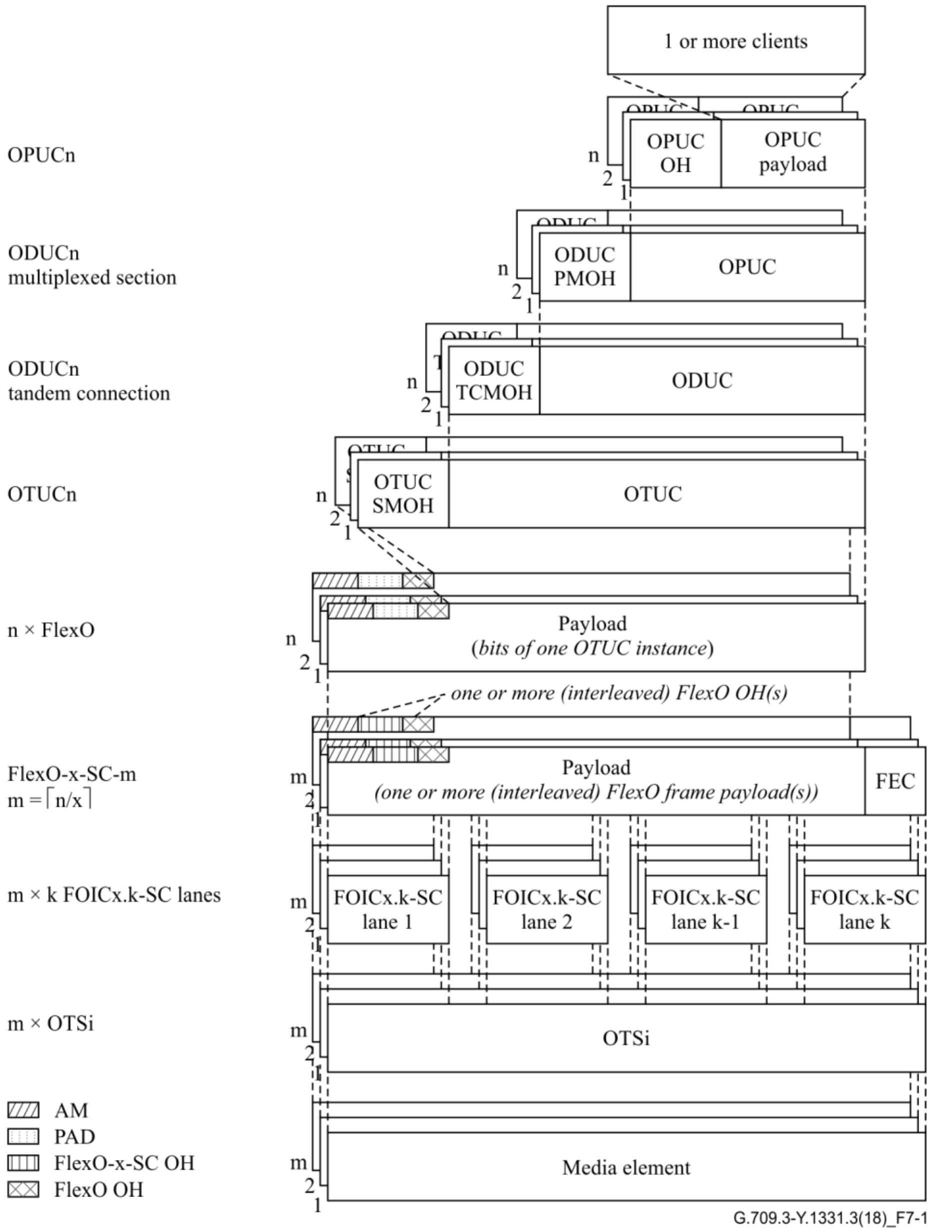

Figure 7-1 – FlexO-x-SC-m interface group principal information containment relationship

7.2 Processing and information flow

Functions and information flows are specified in [ITU-T G.798].

8 FlexO frame

Refer to clause 8 of [ITU-T G.709.1].

9 Alignment markers, PAD and FlexO overhead

Refer to clause 9 of [ITU-T G.709.1].

NOTE – [ITU-T G.709] excludes the use of a SOTUm to carry time synchronization information. This implies that the FlexO OSMC overhead is not applicable and reserved for the FlexO-x-F interface when deployed on a SOTUm. When deployed on a longer reach SOTU or MOTU interface, FlexO OSMC overhead is applicable.

10 Mapping of OTUCn signal into n FlexO instances

Refer to clause 10 of [ITU-T G.709.1].

Deskewing in the sink process is performed between OTUC instances within the OTUCn as specified in [ITU-T G.709.1].

The skew requirements are intended to account for variations due to digital mapping, cable lengths and frequency slot related delay differences for relevant applications as defined by [ITU-T G.698.2]. The skew tolerance requirement for OTUC instances within an OTUCn that is carried over longer reach FlexO interface groups is 1 µs.

NOTE – This value of 1 µs is larger than the 300 ns value specified in [ITU-T G.709.1] for short reach interface groups.

11 m×100G FlexO with staircase FEC interface group (FlexO-1-SC-m)

A FlexO-1-SC-m interface group consists of m FlexO-1-SC interfaces.

11.1 FlexO-1-SC frame structure

The 100G FlexO-1-SC frame structure is shown in Figure 11-1 and consists of 128 rows by 5,485 1-bit columns. It contains one FlexO frame structure as defined in clause 8, extended with a SC FEC parity area in columns 5141 to 5485 in every row and a 60-byte FlexO-1-SC OH area in row 1 columns 481 to 960.

NOTE – The FlexO-1-SC OH area is reusing the pad area (PAD) overhead field of the FlexO frame.

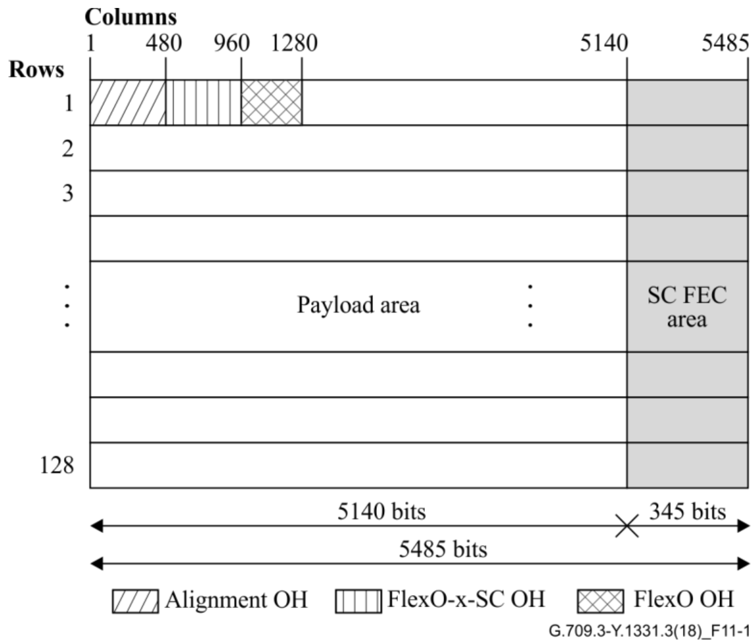

Figure 11-1 – 100G FlexO-1-SC frame structure

To accommodate the block length of the staircase FEC, which is not aligned with the 100G FlexO-1-SC frame length, an additional SC FEC block group (FBG) structure is superimposed on the underlying FlexO-1-SC frame structure (see Figure 11-2, left).

The FEC block group (FBG) consists of 238 consecutive FlexO-1-SC frame rows (of 5485-bit each), which map to five contiguous base blocks. The FBG contains 5×244,664 information and 5×16384 parity bits plus 5×38 FlexO-1-SC OH bits that are located between the parity bits of successive SC FEC blocks. A FBG contains the information bits of five SC FEC blocks B_i to B_{i+4} and parity bits of five SC FEC blocks B_{i-1} to B_{i+3}.

The boundaries of these five SC FEC information, parity and FlexO-1-SC overhead blocks within a FBG are defined in Table 11-1 and illustrated in the right segment of Figure 11-2. The start of the FBG is identified through a SC FEC block row number indication carried in the FBA field of the FlexO-1-SC overhead, part 1 (see Figure 11-3).

Table 11-1 – SC FEC information, parity and FlexO-1-SC part 2 overhead block boundaries

	Information blocks {row,column}	**Parity blocks {row,column}**	**FlexO-1-SC part 2 OH {row,column}**
1st block	From {j+1,1} to {j+48,3084}	From {j+1,5141} to {j+48,5309}	From {j+48,5310} to {j+48,5347}
2nd block	From {j+48,3085} to {1+96,1028}	From {j+48,5348} to {1+96,5171}	From {j+96,5172} to {i+96,5209}
3rd block	From {j+96,1029} to {j+143,4112}	From {j+96,5210} to {j+143,5378}	From {j+143,5379} to {j+143,5416}
4th block	From {j+143,4113} to {j+191,2056}	From {j+143,5417} to {j+191,5240}	From {j+191,5241} to {j+191,5278}
5th block	From {j+191,2057} to {j+238,5140}	From {j+191,5279} to {j+238,5447}	From j+191,5448} to {j+238,5485}

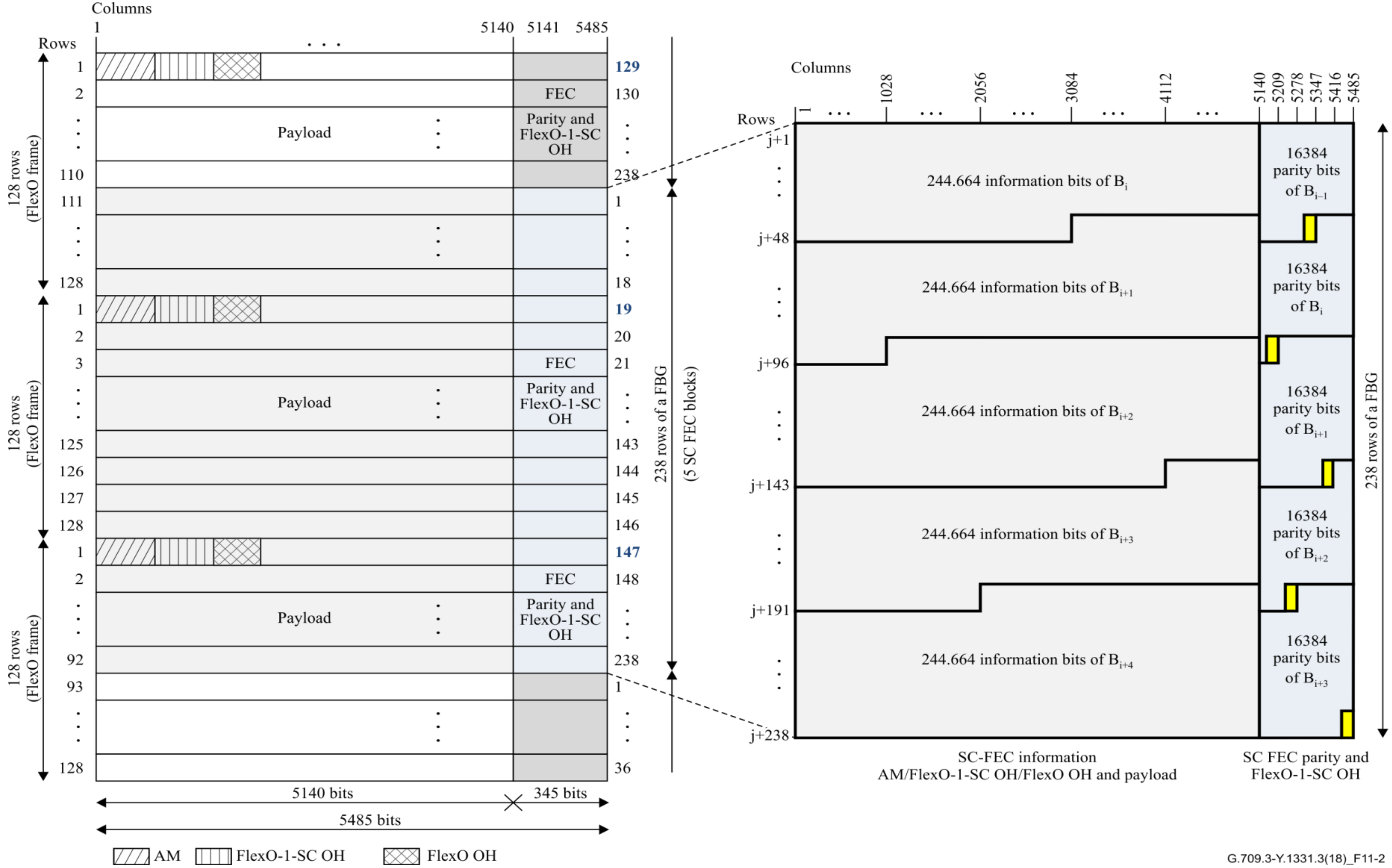

Figure 11-2 – 100G FlexO-1-SC's FBG structure (left) and information and parity block and FlexO-1-SC OH boundaries (right)

11.2 FlexO-1-SC bit rate and frame periods

The bit rate and tolerance of the 100G FlexO-1-SC signal is defined in Table 11-2.

Table 11-2 – FlexO-1-SC types and bit rates

100G FlexO-1-SC nominal bit rate	Bit-rate tolerance
524366/462961 × 99 532 800 kbit/s	±20 ppm
NOTE 1 – The nominal FlexO-1-SC bit rate is approximately: 112 734 368.996 kbit/s. NOTE 2 – The FlexO-1-SC bit rate can be based on the OTUC bit rate as follows: 4388/4097 × OTUC bit rate = 4388/4097 × 239/226 × 99 532 800 kbit/s. NOTE 3 – The FlexO-1-SC bit rate can be based on the FlexO-1-RS bit rate as follows: 1097/1088 × FlexO-1-RS bit rate = 1097/1088 × 256/241 × 239/226 × 99 532 800 kbit/s.	

The frame and multi-frame periods of the FlexO-1-SC signal are defined in Table 11-3.

Table 11-3 – FlexO-1-SC frame and multi-frame periods

Frame period (Note)	Multi-frame period (Note)
~6.228 µs	49.822 µs
NOTE – The period is an approximated value, rounded to 3 decimal places.	

11.3 FlexO-1-SC overhead

The FlexO-1-SC frame contains two overhead areas. The first overhead area is located in the 480 bits in row 1, columns 481 to 960. It includes information to support the FBG alignment function in the first 8 bits, while the remaining 472 bits are reserved for future international standardization. The second overhead area is located in the FlexO-1-SC FEC parity area, in blocks of 38 bits each between two successive SC FEC blocks.

The FlexO-1-SC OH is terminated where the FlexO-1-SC frame is assembled and disassembled.

An overview of the first part of the FlexO-1-SC OH area is presented in Figure 11-3. An overview of the second part of the FlexO-1-SC OH area is presented in Figure 11-2 and Figure 11-4.

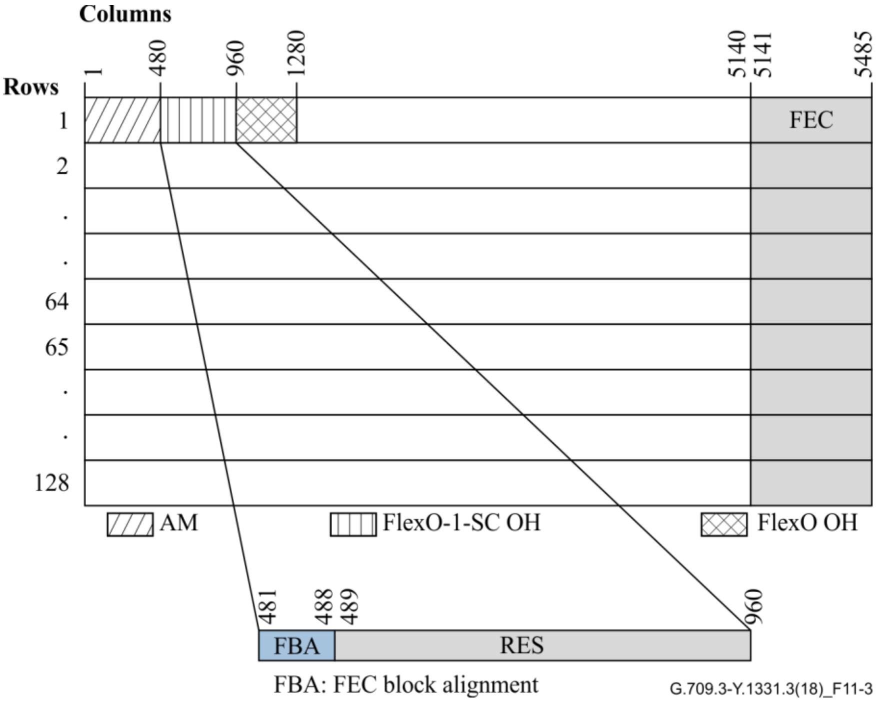

Figure 11-3 – FlexO-1-SC overhead, part 1

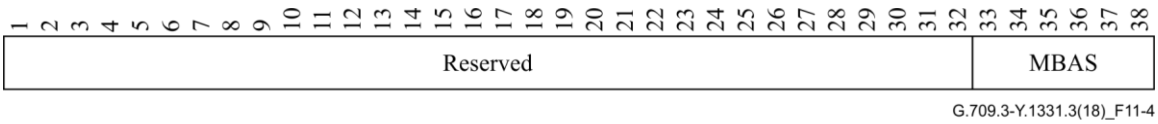

Figure 11-4 – FlexO-1-SC overhead, part 2

11.3.1 FlexO-1-SC FEC block alignment (FBA)

Figure 11-3 shows the "FBA" overhead byte in byte 1 of the first part of the FlexO-1-SC overhead area. The FEC block alignment (FBA) carries an 8-bit value indicating the current row number in the range 1 (0b0000 0000) to 238 (0b1110 1101) within the 238 FlexO-1-SC rows sequence of a FBG. Refer to Figure 11-5 for the encoding of the FBA values.

This row number value is used in the far end decoder to synchronize a 238 row counter that indicates the start of each FBG.

FBA = 1 (encoded as 0b0000 0000) means that the next start of a FBG is in this FlexO-1-SC frame row. FBA > 1 means that the next start of a FBG is (238 – FBA + 1) FlexO-1-SC frame rows later.

Successive FBA values will have the following relationship:

FBA(t) = 1 + (FBA(t-1) – 1 + 128) mod 238.

The FBA sequence repeats every 238 FlexO-1-SC frames. The 238 FBA sequence contains the FBA values *1*,*129*, *19*, *147*, *37*, *165* at the start of the sequence and FBA values *93*, *221*, *111* at the end of the sequence. An example illustrating FBA values of 129, 19 and 147 is presented in Figure 11-6.

	8-bit FEC block alignment encoding							
	1	2	3	4	5	6	7	8
				:				
238	1	1	1	0	1	1	0	1
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1
3	0	0	0	0	0	0	1	0
4	0	0	0	0	0	0	1	1
5	0	0	0	0	0	1	0	0
6	0	0	0	0	0	1	0	1
7	0	0	0	0	0	1	1	0
				:				
				:				
236	1	1	1	0	1	0	1	1
237	1	1	1	0	1	1	0	0
238	1	1	1	0	1	1	0	1
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	1	0
				:				

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Figure 11-5 – FlexO-1-SC FEC block alignment (FBA) signal overhead

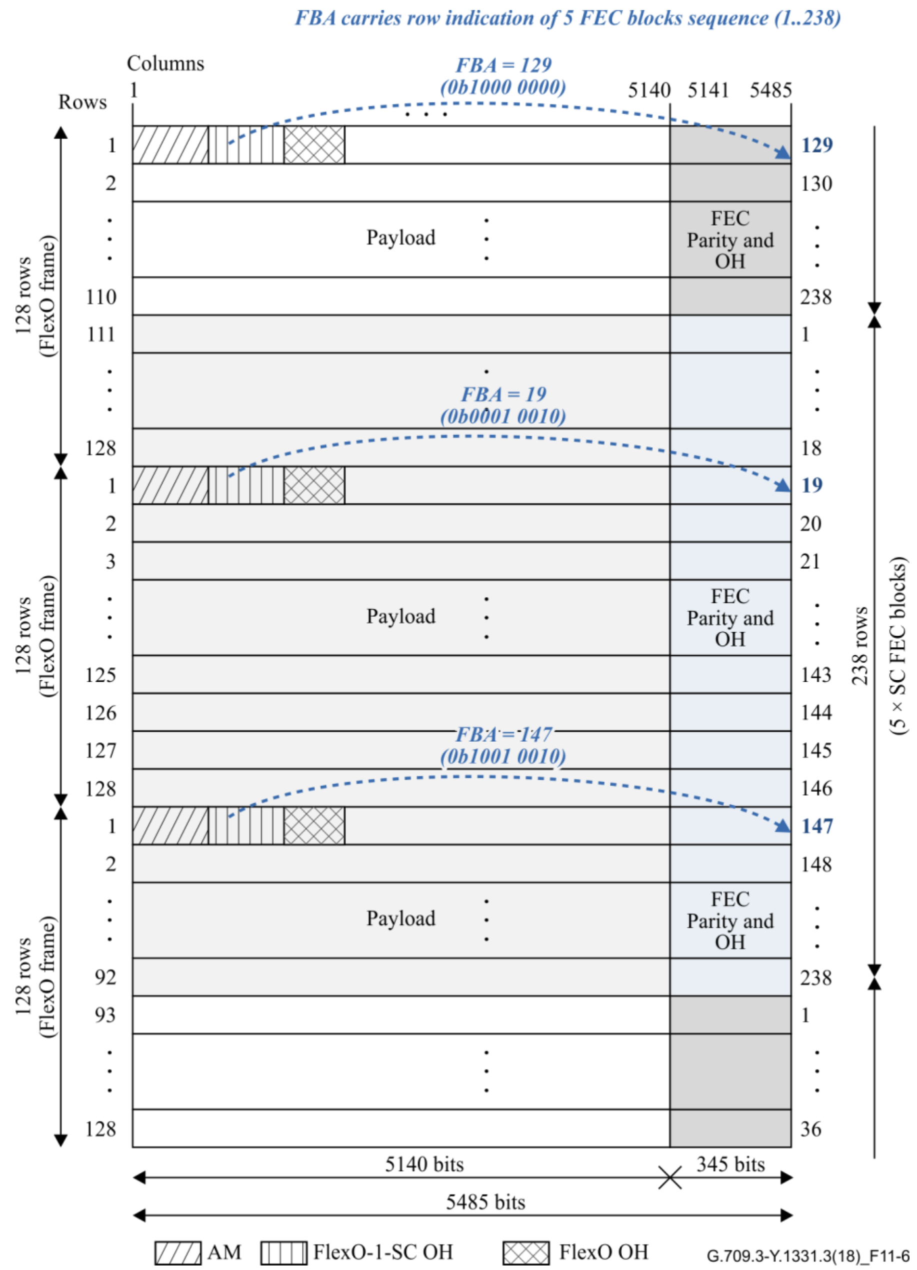

Figure 11-6 – FlexO-1-SC FEC block alignment (FBA) signal operation example

11.3.2 Multi block alignment signal (MBAS)

To synchronize the state of the Error Decorrelator (ED) controllers between the receiver and the transmitter, the staircase FEC scheme uses a 7-bit SC FEC multi block alignment signal (MBAS) which provides a 128 block sequence.

The six most significant bits of the 7-bit MBAS are transferred between source and sink in the 6-bit MBAS overhead, which is located in bits 33 to 38 of the second part of the FlexO-1-SC OH area.

The numerical value represented in the six MBAS overhead bits will be incremented every two SC FEC blocks and provides as such a 128-block multi-block as illustrated in Figure 11-7.

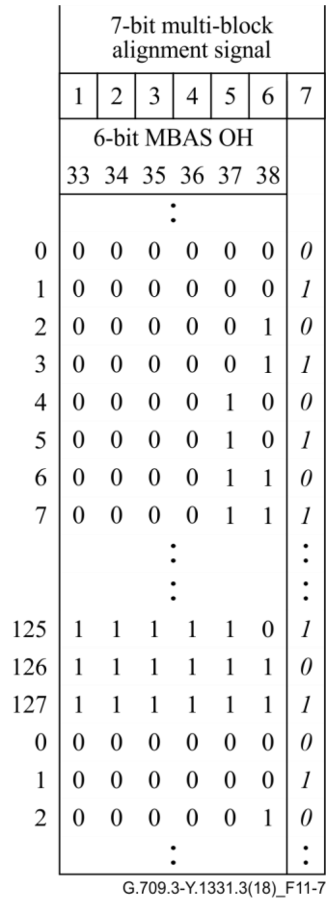

Figure 11-7 – Multi-block alignment signal overhead

11.4 Staircase forward error correction (SC FEC)

The FlexO-1-SC FEC code is a 512-bit × 510-bit generalized staircase code (SC FEC) that works in conjunction with an error decorrelator. The error decorrelator function is used to randomize the error locations, in order to reduce impact of correlated errors on the decoder performance of the random error correcting SC FEC. The SC FEC code is systematic and the 6.7% FlexO-1-SC FEC area specified in clause 11.1 is used to store the parity information generated by the encoder.

The operation of a generic staircase FEC scheme (with error de-correlator) is specified in Annex A. The FlexO-1-SC specific aspects of the staircase FEC operation are specified in Annex B.

11.5 FlexO-1-SC scrambling

The FlexO-1-SC signal must have sufficient bit timing content at the network node interface (NNI). A suitable bit pattern, which prevents a long sequence of "1"s or "0"s, is provided by using an additive scrambler.

Scrambling of the FlexO-1-SC signal is performed after SC FEC parity computation and insertion into the FEC parity area of the FlexO-1-SC signal.

The operation of the scrambler shall be functionally equivalent to that of a frame-synchronous additive scrambler with a sequence length of 65535 and the generating polynomial shall be $x^{16} + x^{12} + x^3 + x + 1$. See Figure 11-3 [ITU-T G.709] for an illustration of this scrambler.

The scrambler state resets to 0xFFFF on the bit in row 1, column 481 and the scrambler state advances with each consecutive bit of the FlexO-1-SC frame (Figure 11-1). The bit in row 1, column 481 and all subsequent bits to be scrambled shall be added modulo 2 to the output from the x^{16} position of the scrambler. The scrambler shall run continuously throughout the complete

FlexO-1-SC frame (including the FEC parity area). The alignment markers (AM) bits shall not be scrambled. See Figure 11-8.

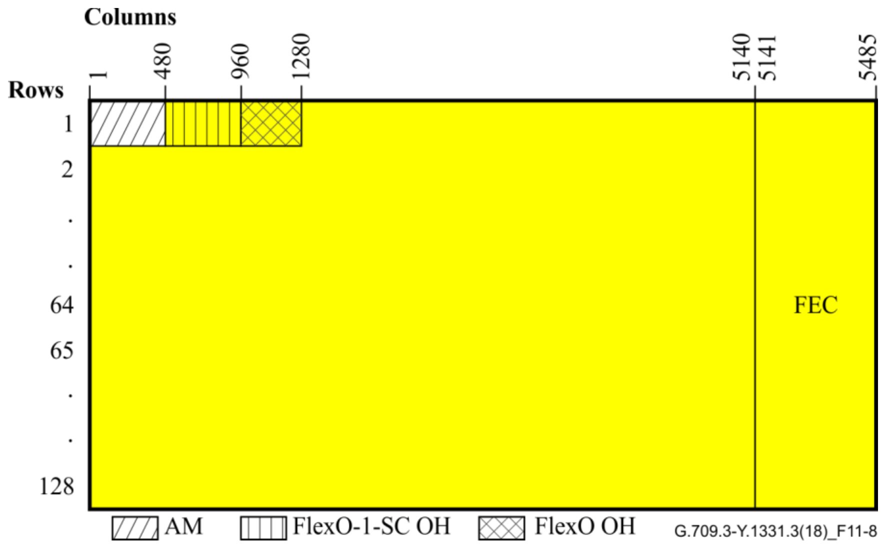

Figure 11-8 – FlexO-1-SC scrambling area

11.6 FOIC1.k-SC

A conceptually serial FlexO-1-SC signal is adapted to a parallel multi-lane distribution (MLD) signal format with k lanes, referred to as FOIC1.k-SC.

11.6.1 FOIC1.4-SC lanes

The FlexO-1-SC bits are distributed to four logical FOIC1.k-SC lanes, in groups of 10-bits, in a round robin distribution scheme from the lowest to the highest numbered lanes. The FOIC1.4-SC interface includes the 10-bit distribution, reordering and deskewing functions following the principles described in clause 11 of [ITU-T G.709.1]. Each FOIC1.4-SC lane is synchronous to the FlexO-1-SC frame.

Each FlexO-1-SC frame contains 5485 × 128 = 702080 bits. Each FOIC1.4-SC lane will carry 25% of these bits, which are 175520 bits, or 17552 10-bit blocks.

The resulting per-lane transmitted values of the AM fields are illustrated in Table 11-3 of [ITU-T G.709.1].

The FOIC1.4-SC interface format is intended for applications defined by application codes for metro networks in [ITU-T G.698.2]. Mapping of the four lanes to and the specification of the optical tributary signal (OTSi) is defined in [ITU-T G.698.2].

11.6.2 FOIC1.4-SC lane skew tolerance requirements

The tolerated skew between lanes in a FOIC1.4-SC interface signal is at least 180 ns.

11.6.3 FOIC1.4-SC 28G lane bit rate

The bit rates and tolerance of the FOIC1.4-SC lanes are defined in Table 11-4.

Table 11-4 – FOIC1.4-SC lane bit rates

FOIC1.4-SC lane nominal bit rate	Bit-rate tolerance
524366/462961 × 24 883 200 kbit/s	±20 ppm
NOTE – The nominal FOIC1.4-SC lane bit rates are approximately: 28 183 592.249 kbit/s.	

Annex A

Forward error correction using 512 × 510 staircase codes

(This annex forms an integral part of this Recommendation.)

Refer to Annex A of [ITU-T G.709.2].

Annex B

Adaptation of 512 × 510 staircase codes to 100G FlexO-1-SC FEC

(This annex forms an integral part of this Recommendation.)

Annex A.2 of [ITU-T G.709.2] describes a generic base block that is used to create the 512 × 510 bit staircase block.

For generating staircase FEC code words of a 100G FlexO-1-SC signal, this base block will be created by mapping the 100G FlexO-1-SC information and FEC bits into it.

Annex B details these mapping specific aspects.

B.1 100G FlexO-1-SC bit and SC FEC specific base blocks mapping relationship

The staircase FEC scheme (with error de-correlator) is specified to operate on base blocks, which contain (8×30592) FEC information bits and (8×2048) FEC parity bits.

The bits of a FBG map into five base blocks. The boundaries of the five information and parity blocks within an FBG are illustrated in Figure B.1.

To compute the FEC parity, the FBG bits in columns 1 to 5140 and the FlexO-1-SC overhead bits in columns 5141 to 5485 are mapped into the first 30952 columns of five consecutive base blocks as illustrated in Figure B.1.

The computed FEC parity bits located in the last 2048 columns of five consecutive base blocks are mapped into 16384 (out of 16422) parity bits in columns 5141 to 5485 of a FBG.

The total number of information bits in a FBG is:

$$238\times5140 \text{ bits} = 1{,}223{,}320 \text{ bit} = 5\times244{,}664 = 5\times [244{,}736 - 72] = 5\times [(512\times478) - 72]$$

The 244,664 information bits of B_{i-1} in FBG row j+1, column 1 to row j+48, column 3084 (see Figure B.1) are mapped to the payload information bits in row 0, column 0 to row 7, column 30519 (i.e., 30591-72) of Base block 1.

The 244,664 information bits of B_i in FBG row j+48, column 3085 to row j+96, column 1028 are mapped to the payload information bits in row 0, column 0 to row 7, column 30519 of the Base block 2.

The 244,664 payload information bits of B_{i+1} in FBG row j+96, column 1029 to row j+143, column 4112 are mapped to the payload information bits in row 0, column 0 to row 7, column 30519 of the Base block 3.

The 244,664 payload information bits of B_{i+2} in FBG row j+143, column 4113 to row j+191, column 2056 are mapped to the payload information bits in row 0, column 0 to row 7, column 30519 of the Base block 4.

The 244,664 payload information bits of B_{i+3} in FBG row j+191, column 2057 to row j+238, column 5140 are mapped to the payload information bits in row 0, column 0 to row 7, column 30519 of the Base block 5.

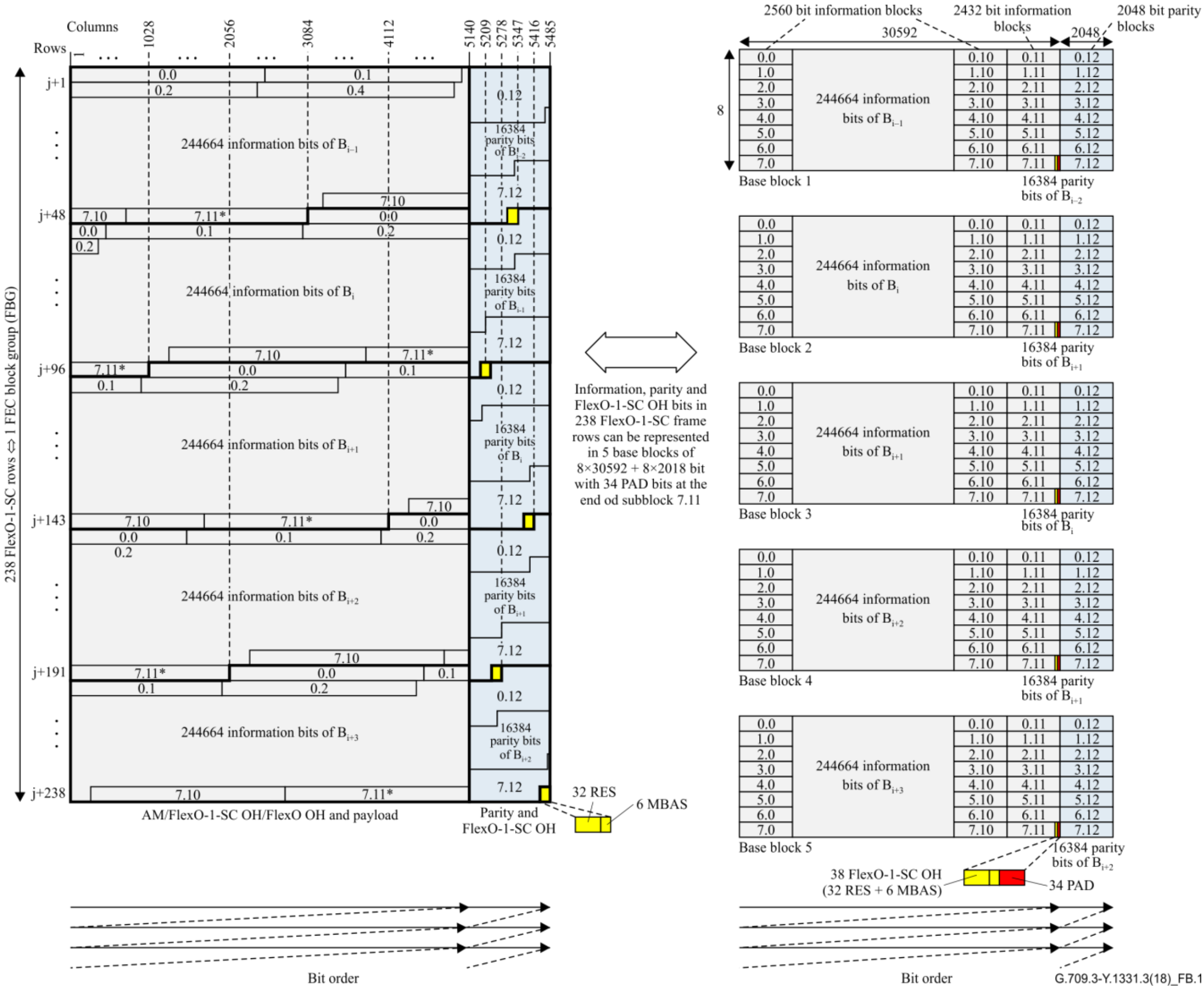

Figure B.1 – 100G FlexO-1-SC bit and SC FEC specific Base Blocks mapping relationship

The 38 FlexO-1-SC overhead bits in FBG row j+48, columns 5310 to 5347 are mapped to the payload information bits in row 7, columns 30520 to 30557 of the Base block 1.

The 38 FlexO-1-SC overhead bits in FBG row j+96, columns 5172 to 5209 are mapped to the payload information bits in row 7, columns 30520 to 30557 of the Base block 2.

The 38 FlexO-1-SC overhead bits in FBG row j+143, columns 5379 to 5416 are mapped to the payload information bits in row 7, columns 30520 to 30557 of the Base block 3.

The 38 FlexO-1-SC overhead bits in FBG row j+191, columns 5241 to 5278 are mapped to the payload information bits in row 7, columns 30520 to 30557 of the Base block 4.

The 38 FlexO-1-SC overhead bits in FBG row j+238, columns 5448 to 5485 are mapped to the payload information bits in row 7, columns 30520 to 30557 of the Base block 5.

The last 34 bits in row 7, columns 30558 to 30591 of the payload information area of Base blocks 1 to 5 are always assumed with an all-zero value for the FEC parity calculations and not transported by FlexO-1-SC.

The total number of FEC parity bits in the 238 FlexO-1-SC frame row sequence is:

$$238\times345 = 82{,}110 \text{ bit} = 5\times16{,}422 = 5\times [38 + 16{,}384] = 5\times [38 + (512\times32)]$$

The 16,384 parity bits in row 0, column 30592 to row 7, column 32639 of Base block 1 are mapped to the 16,384 parity bits of B_{i-2} in FBG row j+1, column 5141 to row j+48, column 5309 (see Figure B.1).

The 16,384 parity bits in row 0, column 30592 to row 7, column 32639 of Base block 2 are mapped to the 16,384 parity bits of B_{i-1} in FBG row j+48, column 5348 to row j+96, column 5171.

The 16,384 parity bits in row 0, column 30592 to row 7, column 32639 of Base block 3 are mapped to the 16,384 parity bits of B_i in FBG row j+96, column 5210 to row j+143, column 5378.

The 16,384 parity bits in row 0, column 30592 to row 7, column 32639 of Base block 4 are mapped to the 16,384 parity bits of B_{i+1} in FBG row j+143, column 5417 to row j+191, column 5240.

The 16,384 parity bits in row 0, column 30592 to row 7, column 32639 of Base block 5 are mapped to the 16,384 parity bits of B_{i+2} in FBG row j+191 column 5279 to row j+238, column 5447.

The bit order of the information bits in columns 1 to 5140 of the FlexO-1-SC frame and the bit order of information bits of the 8×30592 bit information base blocks is the same, and is from left-to-right and top-to-bottom.

The bit order of the parity bits in columns 5141 to 5485 of the FlexO-1-SC frame and the bit order of parity bits of the 8×2048 bit parity base blocks is the same, and is from left-to-right and top-to-bottom.

B.2 100G FlexO-1-SC transmitter and receiver SC FEC processing

Figure B.2 presents a 100G FlexO-1-SC specific version of Figure A.1 from [ITU-T G.709.2]. In Figure B.2, the "Input frame without FEC parity", "Output frame with SC FEC parity" and "Output frame without FEC parity" blocks within Figure A.1 of [ITU-T G.709.2] are replaced by a "100G FlexO-1" block that contains 244,664 information bits, a "FlexO-1-SC" block that contains 244,664 information, 16384 parity and 38 overhead bits and a "100G FlexO-1' block that contains 244,664 information bits, respectively. Furthermore, it is illustrated that the first 30592 columns of a base block in Figure B.2 contain "32 RES, 6 MBAS and 34 PAD" bits instead of "72 PAD" bits.

A vector of 244,664 information bits from a FBG is distributed and mapped into the first 30592 columns of a base block together with 38 overhead (32 RES + 6 MBAS) bits and 34 PAD bits. Then the staircase FEC specific transmit side processing is performed and 16,384 parity bits become available in the last 2048 columns of a base block. FlexO-1-SC information and overhead (32 RES + 6 MBAS) bits plus computed parity bits are then mapped into the 100G FlexO-1-SC frame format.

At the receive side the information, overhead and parity bits in the FlexO-1-SC signal are mapped into information and parity areas of base blocks. Then the staircase specific receive side processing is performed and decoded information bits are stored in the first 30592 columns of a base block. The information bits are then mapped to the 100G FlexO-1 frame format.

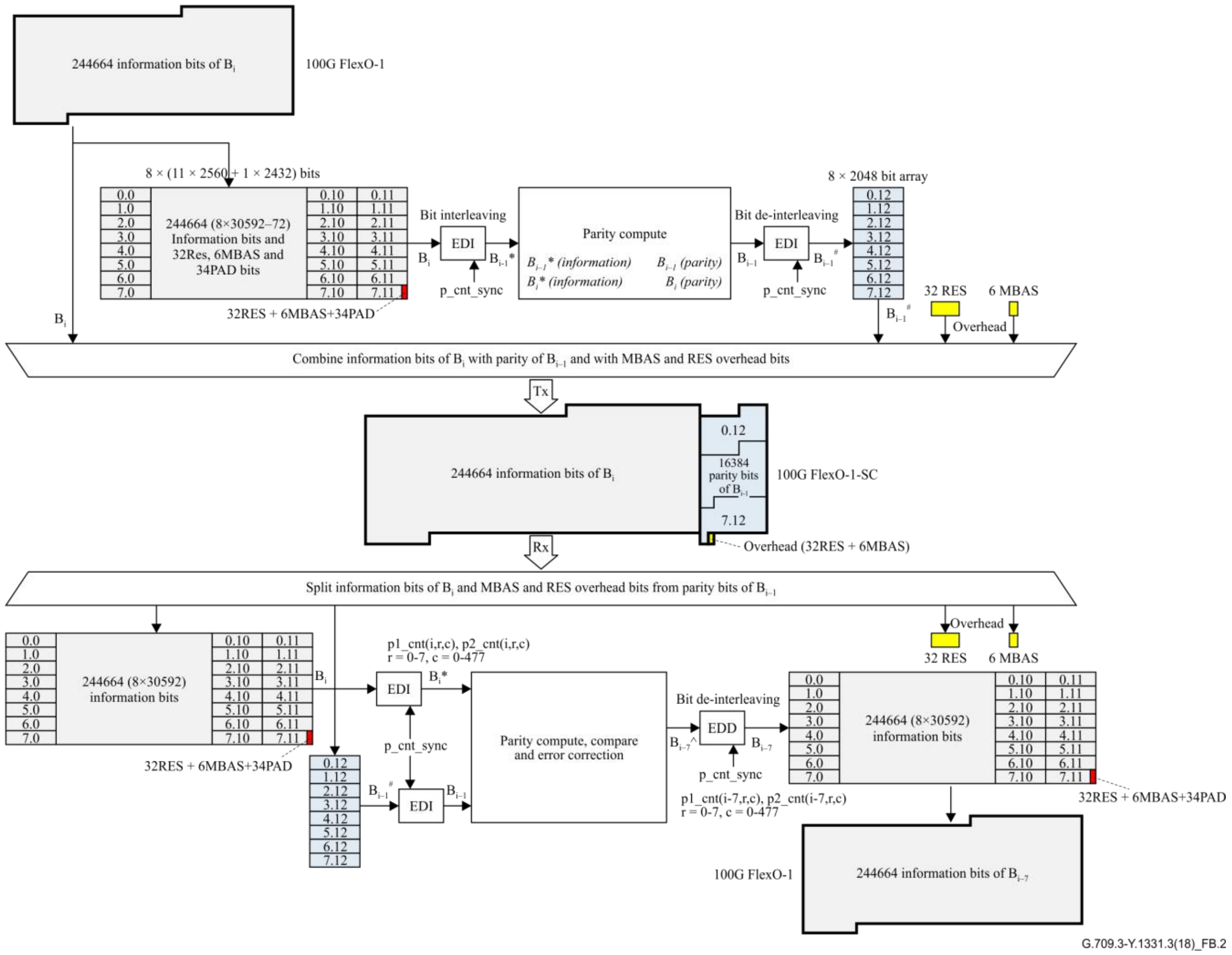

Figure B.2 – 100G FlexO-1-SC transmitter and receiver SC FEC processing

Appendix I

Example applications

(This appendix does not form an integral part of this Recommendation.)

FlexO-x-SC group interfaces can be used for a variety of applications.

Example applications for a FlexO-x-SC-m interface group are shown in Figure I.1 and Figure I.2. Such an interface group might represent an OTN handoff between router (R) and transport (T) nodes within one administrative domain, or could be a handoff between OTN equipment of different vendors in one administrative domain.

Optical transport networks are typically subdivided into metro and core where the core interconnects metro networks. Transport services may stay in one metro network or they may extend over different ones. In the latter case they may be passed through the core network.

Network elements in the metro network play different roles such as metro/core gateway, edge towards customer and transit nodes. The customer facing functions lead to some diversity of client interfaces. Network elements from different vendors may be used to serve this broad scope of functions. FlexO-LR interfaces could be used to interconnect network elements of different vendors or the same vendor.

Figure I.1 illustrates an OTN core network with associated metro networks. The figure shows:

– OTN ODU cross connect nodes with electrical switch fabric (labelled EXC) of vendor Z or X interconnected with EXC of vendor X using a FlexO-x-SC-m interface group
– packet switching nodes (labelled Router) of vendor Z interconnected with the router of vendor X using a FlexO-x-SC-m interface group
– interconnection of the above EXC or router nodes through a metro OTN network
– interconnection of the above EXC or router nodes, establishing a path over which the OCh or OTSiA overhead can be exchanged as specified in [ITU-T G.872], [ITU-T G.709] and [b-ITU-T G.7712] enabling end-to-end optical path monitoring
– interconnection in backbone/core network is also possible if the FlexO-x-SC FEC is adequate

Details of the optical path passed by the FlexO-x-SC signals are defined in [ITU-T G.698.2].

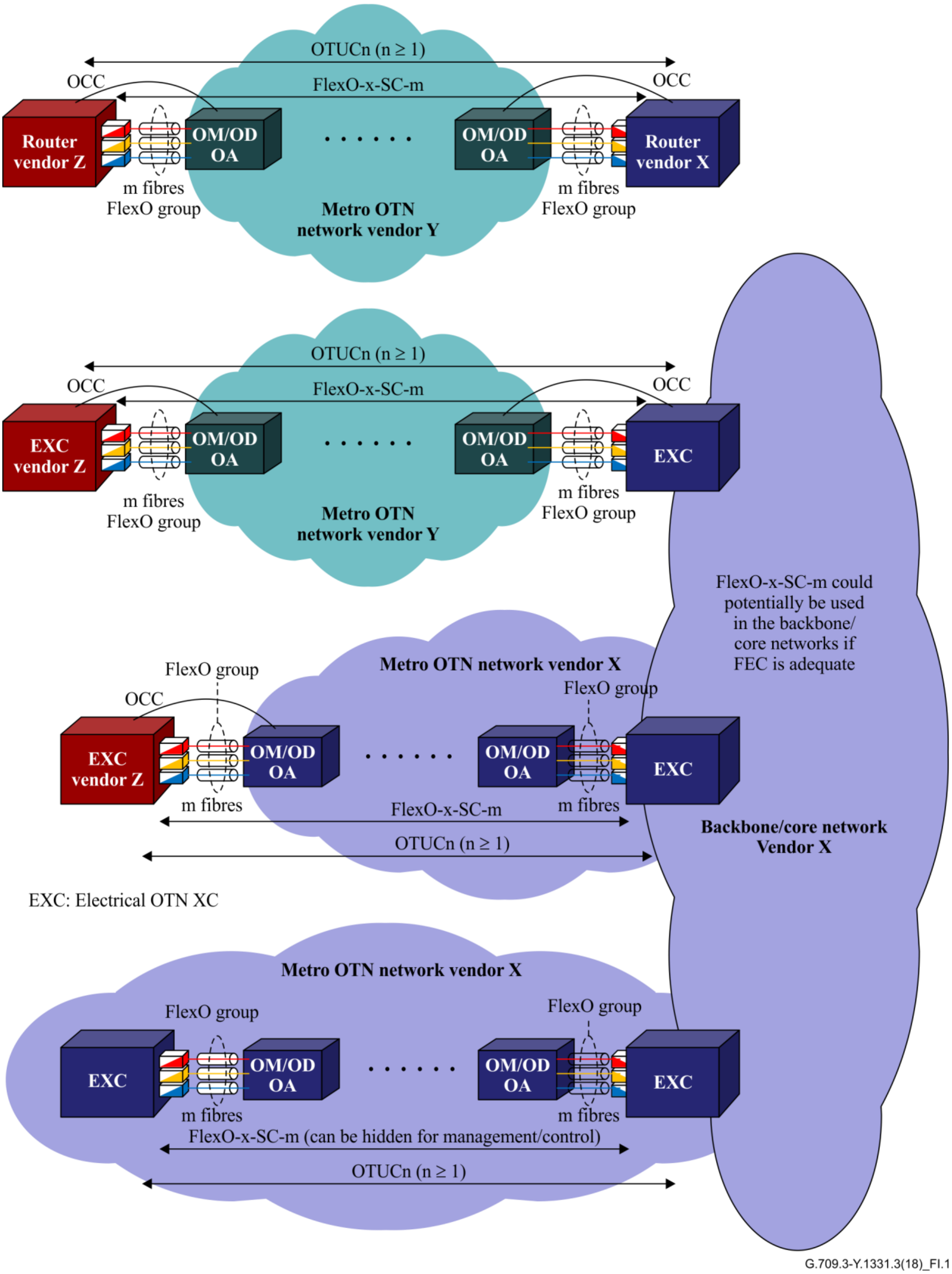

Figure I.1 – Example FlexO-x-SC-m deployments in one administrative domain

Figure I.2 illustrates interconnection of the EXC or router nodes through a set of m point-to-point fibres, establishing an inter-domain group interface beyond the distances supported by the FlexO-x-RS-m specified in [ITU-T G.709.1] and [b-ITU-T G.959.1].

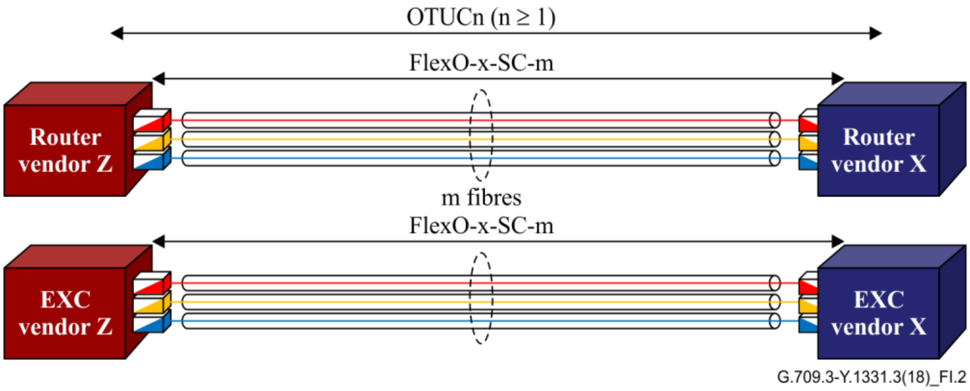

Figure I.2 – Example FlexO-x-SC-m deployments establishing an inter-domain group interface beyond the distances supported by the FlexO-x-RS-m

Bibliography

[b-ITU-T G.959.1] Recommendation ITU-T G.959.1 (2018), *Optical transport network physical layer interfaces*.

[b-ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2010), *Architecture and specification of data communication network*.

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