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**Supplement 58**

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

## Optical transport network module framer interfaces

ITU-T G-series Recommendations – Supplement 58

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# Supplement 58 to ITU-T G-series Recommendations

## Optical transport network module framer interfaces


### Summary

Supplement 58 to ITU-T G-series Recommendations describes several interoperable component to component multilane interfaces (across different vendors) to connect an optical module (with or without digital signal processor (DSP)) to a framer device in a vendor's equipment supporting 25G, 40G, 50G, 100G or beyond 100G optical transport network (OTN) interfaces.

Only the structure of the 11G, 28G or 56G physical lanes of the different OTN module framer interface (MFI) examples is provided in this Supplement. Electrical parameters for these interfaces can use specifications provided in the relevant clauses of OIF-CEI implementation agreement (IA) specifications. For their electrical characteristics, the OIF-CEI IA specifications can be used.

This Supplement relates to ITU-T Recommendation ITU-T G.709/Y.1331.



### History

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### Keywords

FOIC, framer, interface, module, module framer interfaces (MFI), optical transport lane (OTL), optical transport network (OTN).


* 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.

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# Optical transport network module framer interfaces

## 1 Scope

This Supplement describes multilane interfaces between an optical transport network (OTN) framer device and an optical module with or without digital signal processor (DSP) (module framer interface). The module framer interfaces (MFIs) described in this Supplement carry optical transport unit k (OTUk; k = 3, 4), optical transport unit 25 or 50 with RS FEC (OTU25-RS or OTU50-RS) or optical transport unit Cn (OTUCn) signals. Electrical parameters for these interfaces can use specifications provided in the relevant clauses of OIF-CEI Implementation Agreement (IA) specifications.

## 2 References

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.695] Recommendation ITU-T G.695 (2018*), Optical interfaces for coarse wavelength division multiplexing applications*.

[ITU-T G.698.2] Recommendation ITU-T G.698.2 (2018), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces*.

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2020), *Interfaces for the optical transport network.*

[ITU-T G.709.1] Recommendation ITU-T G.709.1/Y.1331.1 (2018), *Flexible OTN short-reach interfaces*.

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

[ITU-T G.709.4] Recommendation ITU-T G.709.4/Y.1331.4 (2020), *OTU25 and OTU50 short-reach interfaces*.

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

## 3 Definitions

None.

## 4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AM Alignment Marker

DSP Digital Signal Processor

FCC FlexO Communications Channel

FEC Forward Error Correction

FlexO Flexible Optical Transport Network

| | |
|---|---|
| FlexO-x | FlexO interface information structure of order Cx (i.e., x * 100G bandwidth capacity) |
| FlexO-x-RS | FlexO interface signal of order Cx with RS10 (544,514) FEC |
| FlexO-x-RS-m | group of m bonded short-reach FlexO-x-RS interfaces carrying an OTUCn |
| FOI | FlexO Interface |
| FOIC1.k-RS | an individual short-reach 100G FlexO-1-RS interface (of order C1) using k parallel physical lanes and carrying one OTUC of an OTUCn |
| FOIC2.k-RS | an individual short-reach 200G FlexO-2-RS interface (of order C2) using k parallel physical lanes and carrying up to two OTUC of an OTUCn |
| FOIC4.k-RS | an individual short-reach 400G FlexO-4-RS interface (of order C4) using k parallel physical lanes and carrying up to four OTUC of an OTUCn |
| IA | Implementation Agreement |
| LD | Local Degrade |
| LLM | Logical Lane Marker |
| MFAS | Multi-Frame Alignment Signal |
| MFI | Module Framer Interface |
| ODSP | Optical Line DSP |
| OH | Overhead area |
| OSMC | OTN Synchronization Messaging Channel |
| OTL | Optical Transport Lane |
| OTLC.4 | group of 4 physical lanes that carry one OTUC of an OTUCn |
| OTLk.n | group of n Optical Transport Lanes that carry one OTUk |
| OTL4.4-SC | group of 4 Optical Transport Lanes that carry one OTU4-SC |
| OTL50.k-RS | group of k physical Lanes with RS10 (544,514) FEC that carry one OTU50 |
| OTL50u.k-RS | group of k physical Lanes with RS10 (544,514) FEC that carry one OTU50u |
| OTN | Optical Transport Network |
| OTUCn | Optical Transport Unit Cn |
| OTUk | Optical Transport Unit k |
| OTU25-RS | Optical Transport Unit 25 with CWM and RS10 (544,514) FEC |
| OTU25u-RS | Optical Transport Unit 25u with CWM and RS10 (528,514) FEC |
| OTU50-RS | Optical Transport Unit 50 with AM and RS10 (544,514) FEC |
| OTU50u-RS | Optical Transport Unit 50u with AM and RS10 (544,514) FEC |
| OTU4-SC | OTU4 with Staircase FEC parity and overhead |
| PAD | Pad Area |
| PAM4 | Pulse Amplitude Modulation, four-level |
| PMD | Physical Medium Dependent sub-layer |
| RS | Reed-Solomon |
| WDM | Wavelength Division Multiplexing |

XLAUI 40 Gbit/s Attachment Unit Interface

## 5 Conventions

Transmission order: The order of transmission of information in all the figures in this Supplement 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 figures.

## 6 Introduction

This Supplement begins with some examples of first generation module framer interfaces (MFIs) for OTU3 and OTU4 signals carried over multiple 11G electrical lanes (using optical transport line OTL3.4 and OTL4.10 structures, respectively).

Then it describes some examples of second generation MFIs for OTU25-RS, OTU50-RS, OTU4 and OTUCn signals carried over 28G electrical lanes (using OTU25-RS, OTL50.2-RS, OTL4.4, OTLC.4, FOIC1.4-RS, FOIC2.8-RS, or FOIC4.16-RS structures, respectively), or for OTU25u-RS or OTU50u-RS carried over one or two 26G electrical lanes (using OTU25u-RS or OTL50u.2-RS, respectively). Note that in the case of an OTUCn signal, n OTLC.4 or m FOICx.k-RS interface structures are used.

Finally, it describes some examples of third generation MFIs for OTU50-RS or OTUCn signal carried over 56G electrical lanes (using OTL50.1-RS, FOIC1.2-RS, FOIC2.4-RS, or FOIC4.8-RS structures, respectively), or for OTU50u-RS carried over one 53G electrical lane (using OTL50u.1-RS). Note that m FOICx.k-RS interfaces (FlexO-x-RS-m group) are used to carry an OTUCn signal.

Users of this Supplement should not assume that possible MFIs are limited to the ones provided in clauses 7, 8 and 9.

## 7 Signal formats and rates carried over 11G electrical lanes

This clause describes some MFI structures using 11G physical lanes in order to carry 40G OTU3 or 100G OTU4 signals. The electrical characteristics of each 11G physical lane may comply with [b-OIF CEI-04.0] CEI-11G-*x*R specifications.

### 7.1 OTL3.4 structure

The original purpose of the OTL3.4 interface, as defined in clause 8.1 and Annex C of [ITU-T G.709], was to enable the re-use of pluggable modules developed for Ethernet 40GBASE-R applications. Modules developed for [b-IEEE 802.3] 40GBASE-LR4 and 40GBASE-ER4 can have corresponding optical specifications for OTU3 interfaces with application codes C4S1-2D1 and C4L1-2D1, respectively, in [ITU-T G.695]. These modules have a four-lane wavelength division multiplexing (WDM) interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These pluggable modules use a four-lane electrical chip-to-module interface (XLAUI), whose specification is found in Annex 83B of [b-IEEE 802.3]. These modules include a simple retimer. This application of the OTL3.4 interface is found in Figure 7-1.

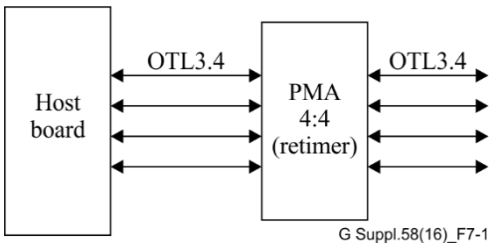



**Figure 7-1 – Illustration of the application of an OTL3.4 interface**

Another application example of the OTL3.4 interface is to connect a 40G optical transport network (OTN) framer and optical line DSP (ODSP) devices in order to carry an OTU3 signal.

The bit rates of the OTL3.4 lanes are specified in [ITU-T G.709] and indicated in Table 7-1.

**Table 7-1 – Bit rates of OTL3.4**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL3.4 | 4 × 255/236 × 9 953 280 kbit/s | ±20 ppm |
| OTL3.4 lane | 255/236 × 9 953 280 kbit/s | ±20 ppm |
| NOTE – The nominal OTL3.4 lane bit rate is approximately: 10 754 603.390 kbit/s. | | |

## 7.2 OTL4.10 structure

The original purpose of the OTL4.10 interface, as defined in clause 8.1 and Annex C of [ITU-T G.709], was to enable the re-use of first-generation pluggable modules developed for Ethernet 100GBASE-R applications. Modules developed for [b-IEEE 802.3] specified 100GBASE-LR4 and 100GBASE-ER4. They have corresponding optical specifications for OTU4 interfaces with the optical parameters as specified for the application codes 4I1-9D1F and 4L1-9C1F, respectively, in [ITU-T G.959.1]. Non-IEEE specified optical interfaces include [ITU-T G.695] application code C4S1-9D1F and [ITU-T G.959.1] application code 4L1-9D1F. These modules have a four-lane WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These first-generation modules connect to the host board via a ten-lane electrical interface. The conversion between ten and four lanes is performed using a 100GBASE-R [b-IEEE 802.3] PMA sublayer as specified in clause 83 of [b-IEEE 802.3]. The specification of the ten-lane electrical chip-to-module interface (CAUI-10) is found in Annex 83B of [b-IEEE 802.3]. The application of the OTL4.10 interface is illustrated in Figure 7-2.

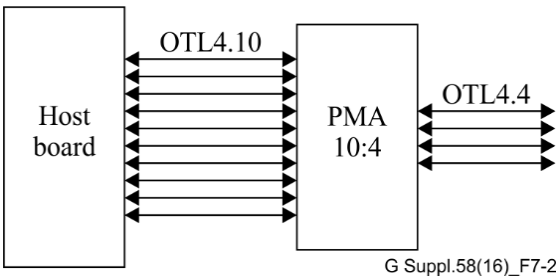



**Figure 7-2 – Illustration of the original application of an OTL4.10 interface**

Another application example of the OTL4.10 interface is to connect first generation 100G OTN framers with optical line DSP (ODSP) devices in order to carry an OTU4 signal.

Each OTL4.10 lane carries two bit-multiplexed logical lanes of an OTU4 as described in Annex C of [ITU-T G.709]. The logical lane format was chosen so that the [b-IEEE 802.3] 10:4 PMA (gearbox) will convert the OTU4 signal between a format of ten lanes of OTL4.10 and four lanes of OTL4.4. Each OTL4.4 lane carries five bit-multiplexed logical lanes of an OTU4 as described in Annex C of [ITU-T G.709].

The bit rate of an OTL4.10 lane is specified in Table 7-2.

**Table 7-2 – Bit rates of OTL4.10**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL4.10 | 10 × 255/227 × 9 953 280 kbit/s | ±20 ppm |
| OTL4.10 lane | 255/227 × 9 953 280 kbit/s | ±20 ppm |
| NOTE – The nominal OTL4.10 lane bit rate is approximately: 11 180 997.357 kbit/s. | | |

## 8 Signal formats and rates carried over 26G or 28G electrical lanes

This clause describes some MFI structures using 28G physical lanes to carry 25G OTU25-RS, 50G OTU50-RS, 100G OTU4 or B100G OTUCn signals, or using 26G physical lanes to carry underclocked 25G OTU25u-RS or 50G OTU50u-RS. The electrical characteristics of each 26G-28G physical lane may comply with [b-OIF CEI-04.0] CEI-28G-*x*R specifications.

### 8.1 OTL4.4 structure

The original purpose of the OTL4.4 interface, as defined in this clause and Annex C of [ITU-T G.709], was to enable the re-use of second (and beyond) generation pluggable modules developed for Ethernet 100GBASE-R applications. Modules developed for [b-IEEE 802.3] specified 100GBASE-LR4 and 100GBASE-ER4. They have corresponding optical specifications for OTU4 interfaces with the optical parameters as specified for the application codes 4I1-9D1F and 4L1-9C1F, respectively, in [ITU-T G.959.1]. Non-IEEE specified optical interfaces include [ITU-T G.695] application code C4S1-9D1F and [ITU-T G.959.1] application code 4L1-9D1F. These modules have a four-lane WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

Most second generation (and beyond) pluggable modules use a four-lane electrical chip-to-module interface (CAUI-4), whose specification is found in Annex 83E of [b-IEEE 802.3]. These modules include a simple retimer (as opposed to the 10:4 gearbox found in first generation modules). This application of the OTL4.4 interface is illustrated in Figure 8-1.

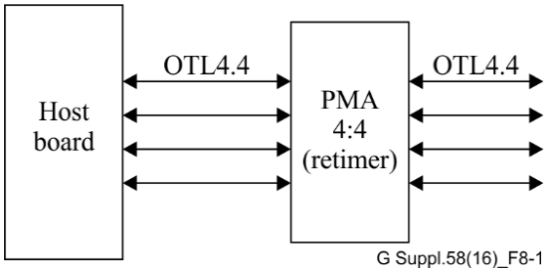



**Figure 8-1 – Illustration of the original application of an OTL4.4 interface**

Another application example of the OTL4.4 interface is to connect second generation multi-100G OTN framers with optical line DSP (ODSP) devices in order to carry independent OTU4 signals and to connect these framers with emerging line side optical modules.

Each OTL4.4 lane carries five bit-multiplexed logical lanes of an OTU4 as described in Annex C of [ITU-T G.709].

The bit rates of the OTL4.4 are specified in [ITU-T G.709] indicated in Table 8-1.

**Table 8-1 – Bit rates of OTL4.4**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL4.4 | 4 × 255/227 × 24 883 200 kbit/s | ±20 ppm |
| OTL4.4 lane | 255/227 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTL4.4 lane bit rate is approximately: 27 952 493.392 kbit/s. | | |

## 8.2 OTLC.4 structure

In B100G OTN design, the interfaces between the B100G OTN framer and ODSP devices will support OTU4 and OTUCn signals. This interface benefits from a common interface format. The purpose of the OTLC.4 interfaces is to support such a common interface format based on the existing OTL4.4 format. These interfaces carry either four physical lanes of an OTU4 (i.e., OTL4.4) or OTUCn (i.e., OTLC.4). See Figure 8-2.

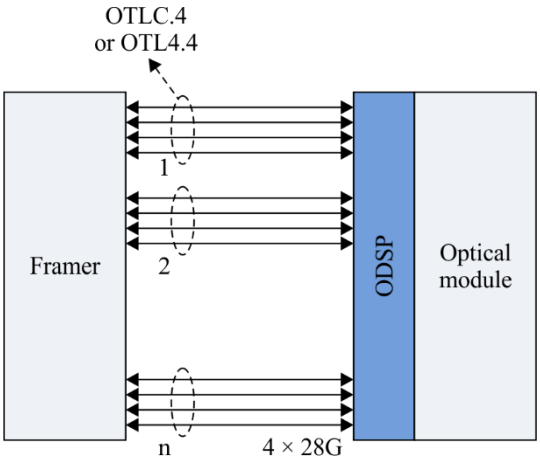



**Figure 8-2 – Example applications of an OTL4.4/OTLC.4 interface**

An OTUCn is split into n times OTUC and each OTUC frame is extended with 256 forward error correction (FEC) columns at the end of the frame which contain a RS (255,239) FEC as specified for the OTUk in Annex A of [ITU-T G.709]. Each OTUC frame with RS (255,239) FEC therefore results in an octet-based block frame structure with four rows and 4080 columns, that is the same as an OTUk (k = 1,2,3,4) frame structure. This frame structure is scrambled as specified for the OTUk in clause 11.2 of [ITU-T G.709] and split into 20 5G OTLC logical lanes as per 5G OTL4 logical lane specification in Annex C of [ITU-T G.709]. 5G OTLC logical lanes are combined into four OTLC.4 physical lanes consistent with the OTL4.4 specifications in Annex C of [ITU-T G.709].

The third OA2 byte in each OTUC with RS (255,239) FEC frame is replaced by a logical lane marker (LLM) byte as per the OTL4.4 specifications in Annex C of [ITU-T G.709] to support the reordering of the 5G OTL4 and OTLC logical lanes within the scope of the 20 logical lanes in a 100G OTU4 or OTUC group.

OTL4.4 physical lanes do not support an OTU4 Identifier. Due to this, groups of four OTLx.4 (x = 4, C) physical lanes carrying one OTU4 or one OTUC instance must be connected as a

100G group. Physical lanes within such a 100G group can be interchanged, but physical lanes of different 100G groups must not be interchanged.

The bit rates of an OTLC.4 lane with RS (255,239) FEC are specified in Table 8-2.

**Table 8-2 – Bit rate of OTLCn with RS (255,239) FEC**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTLCn | n × 4 × 255/226 × 24 883 200 kbit/s | ±20 ppm |
| OTLC slice | 4 × 255/226 × 24 883 200 kbit/s | ±20 ppm |
| OTLC.4 lane | 255/226 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTLCn, OTLC slice and OTLC.4 lane bit rates are approximately and respectively: n × 112 304 707.965 kbit/s, 112 304 707.965 kbit/s and 28.076 176.991 kbit/s. | | |

## 8.3 FOIC1.4-RS structure

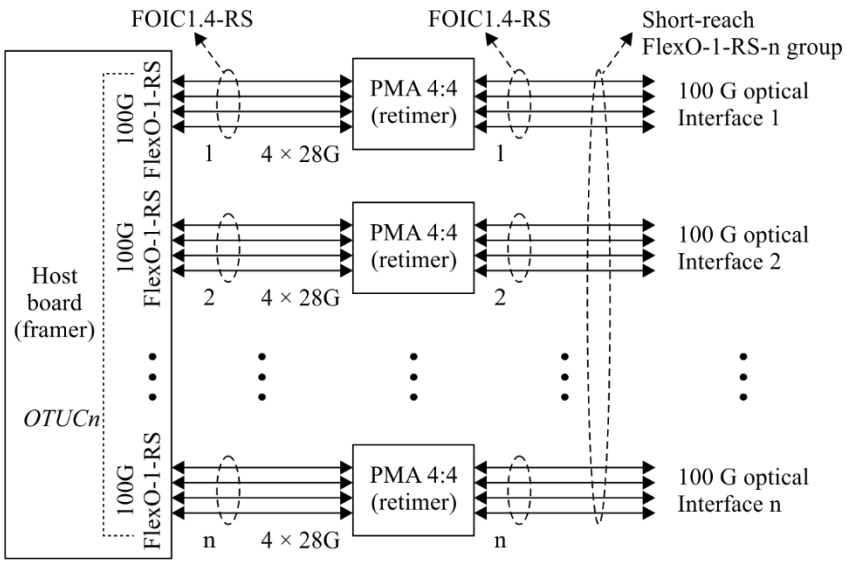
The original purpose of the n*FOIC1.4-RS interface (i.e., FlexO-1-RS-n group), as defined in clause 11 of [ITU-T G.709.1], is to provide an interoperable modular short-reach OTN interface for B100G OTUCn (n ≥ 1) transport signals, by bonding n * 100G standard-rate interfaces.

As the OTUCn is split into n times OTUC, each individual 100G FlexO-1-RS interface (carrying an OTUC) is distributed on four lanes (FOIC1.4-RS) and operates at almost the same interface rate as OTL4.4 (with just −4.46 ppm offset between the two nominal rates).

So, second (and beyond) generation pluggable modules developed for Ethernet 100GBASE-R applications and supporting the OTU4 rate and OTL4.4 interface could be seamlessly reused for 100G FlexO-1-RS transport and FOIC1.4-RS interface. Modules developed for [b-IEEE 802.3] specified 100GBASE-LR4 and 100GBASE-ER4. They have corresponding optical specifications for OTU4 (and so for 100G FlexO-1-RS) interfaces with the optical parameters as specified for the application codes 4I1-9D1F and 4L1-9C1F, respectively, in [ITU-T G.959.1]. Non-IEEE specified optical interfaces include [ITU-T G.695] application code C4S1-9D1F and [ITU-T G.959.1] application code 4L1-9D1F. These modules have a four-lane WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

Most of these pluggable modules use a four-lane electrical chip-to-module interface (CAUI-4), whose specification is found in Annex 83E of [b-IEEE 802.3] and include a simple retimer.

This application of n*FOIC1.4-RS bonded interfaces (short-reach FlexO-1-RS-n group) is illustrated in Figure 8-3a.

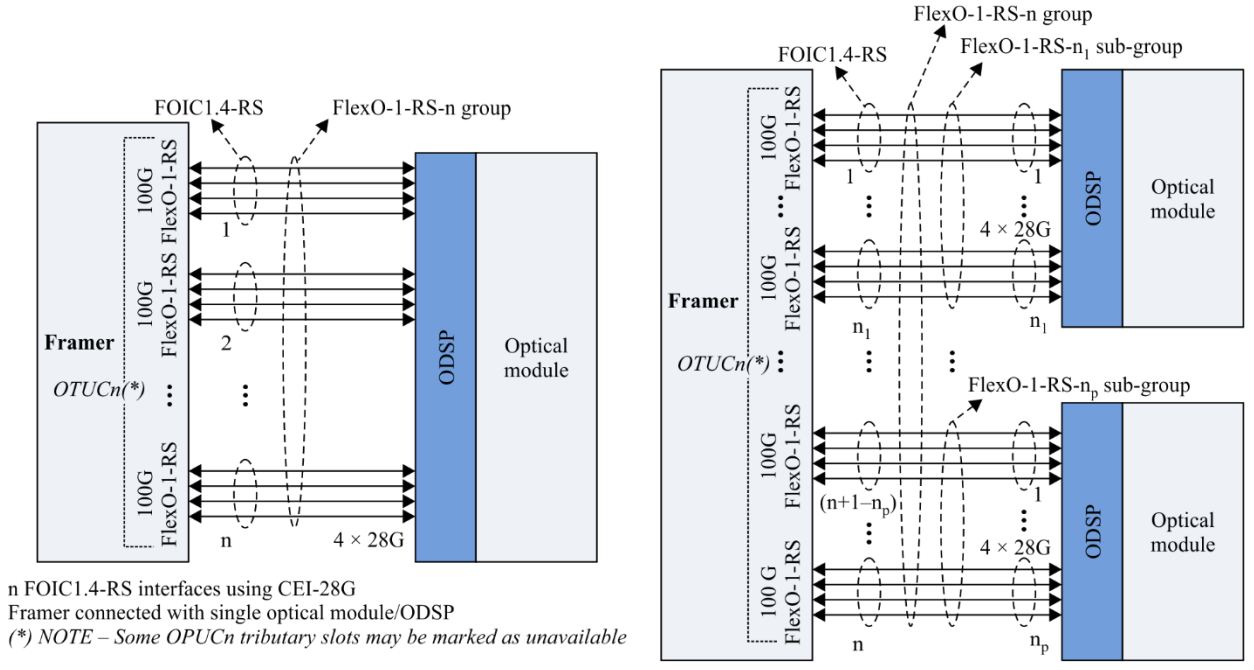



n FOIC1.4-RS interface using CEI-28G to n bonded 100G optical modules

G Suppl.58(18-10)_F8-3a

**Figure 8-3a – Original application of a FOIC1.4-RS interface**

NOTE – The FOIC1.4-RS interface could also be used similarly to an OTLC.4 interface to connect a beyond 100G OTN framer with one or more optical line DSP (ODSP) devices supporting FlexO interfaces on the host side. One possible advantage for implementers is that the FOIC1.4-RS lane operates at the same rate as an OTL4.4 lane, so slightly slower than an OTLC.4 lane and with a stronger RS10 FEC. Another advantage is that the bit rate of a FOIC1.4-RS lane is exactly half the bit rate of a FOIC1.2-RS lane (the FOIC1.2-RS lane is obtained by simple bit-interleaving of two FOIC1.4-RS lanes). Depending on the application, implementers could make use of the FlexO overhead. Although some overhead may become optional, they are generated at the source and may be ignored at the sink (see clause 9.1 for the handling of FlexO overhead for this type of application). This alternate application is illustrated in Figure 8-3b.




n FOIC1.4-RS interfaces using CEI-28G
Framer connected with single optical module/ODSP
*(*) NOTE – Some OPUCn tributary slots may be marked as unavailable*

n FOIC1.4-RS interfaces using CEI-28G
Framer connected with p optical module/ODSPs ($n_1+n_2+..+n_p = n$)
*(*) NOTE – Some OPUCn tributary slots may be marked as unavailable*

G Suppl.58(18-10)_F8-3b

**Figure 8-3b – Alternate application of a FOIC1.4-RS interface**

The bit rates of the FOIC1.4-RS are specified in [ITU-T G.709.1] indicated in Table 8-3.

**Table 8-3 – Bit rates of short-reach FlexO-1-RS--n and FOIC1.4-RS**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-1-RS-n | n × 4 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC1.4-RS | 4 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC1.4-RS lane | 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC1.4-RS lane bit rate is approximately: 27 952 368.611 kbit/s. | | |

## 8.4 FOIC2.8-RS and FOIC4.16-RS structures

As shown in Figures 7-1 and 10-1 of [ITU-T G.709.1], an OTUCn signal (n ≥ 1), full-rate or sub-rated (with some OPUCn Tributary Slots marked as unavailable), can be carried over m*FOIC2.8-RS or m*FOIC4.16-RS bonded interfaces (short-reach FlexO-x-RS-m group, with {x,k} = {2,8} or {4,16} respectively). Each FOIC2.8-RS interface contains eight physical lanes of a 200G FlexO-2-RS frame (carrying up to two OTUC). Each FOIC4.16-RS interface contains sixteen physical lanes of a 400G FlexO-4-RS frame (carrying up to four OTUC).

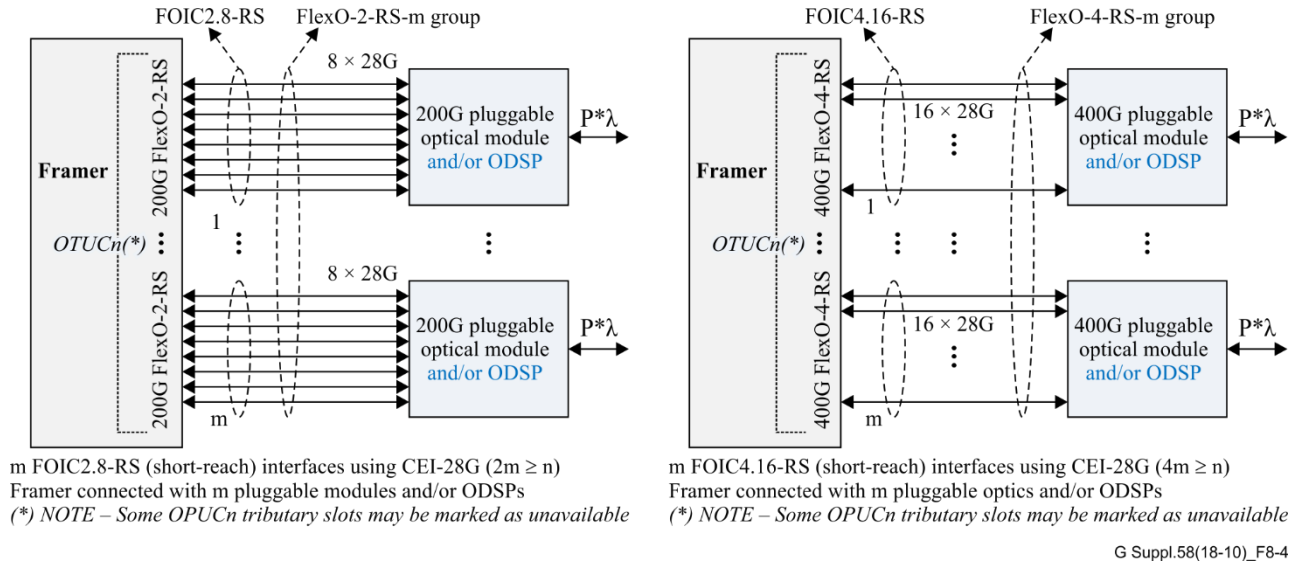
This provides interoperable modular OTN interfaces with short-reach FEC (reusing same KP4 RS10 FEC schemes as 200GBASE-R or 400GBASE-R) for B100G OTUCn (n ≥ 1) transport signals, by bonding m * 200G or m * 400G standard-rate interfaces.

The FOIC2.8-RS or FOIC4.16-RS interface could be used to connect a beyond 100G OTN framer with one or more 200G or 400G pluggable modules or ODSP devices supporting 28G electrical lanes and FlexO interfaces on the host side. One possible advantage for implementers is that the FEC and lane processing for 200G FOIC2.8-RS or 400G FOIC4.16-RS interface is almost identical to 200GAUI-4 or 400GAUI-8, respectively, thus allowing implementers to share digital logic supporting both Ethernet and OTN signals on its host side.

First generation pluggable modules developed for Ethernet 200GBASE-R with eight electrical lanes on the host side and supporting 200G FlexO rate and FOIC2.8-RS host interface (roughly the same bit rate as OTL4.4 bit rate per 28G lane with similar digital format as 200GAUI-8) could also be reused for 200G FlexO-2-RS transport. They have corresponding optical specifications with optical parameters as specified for the pulse amplitude modulation, four-level (PAM4) application codes 4I1-4D1F in [ITU-T G.959.1] and C4S1-4D1F in [ITU-T G.695]. These modules have a four-lane WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

Similarly, first generation pluggable modules developed for Ethernet 400GBASE-R with sixteen electrical lanes on the host side and supporting 400G FlexO rate and FOIC4.16-RS host interface (that is roughly the same bit rate as OTL4.4 bit rate with similar digital format as 400GAUI-16) could be reused for 400G FlexO-4-RS transport. They have corresponding optical specifications with optical parameters as specified for the PAM4 application codes 8R1-4D1F or 8I1-4D1F in [ITU-T G.959.1]. These modules have an eight-lane WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These applications of m*FOIC2.8-RS bonded interfaces (short-reach m*200G FlexO-2-RS-m group) and m*FOIC4.16-RS bonded interfaces (short-reach m*400G FlexO-4-RS-m group) are illustrated in Figure 8-4.




m FOIC2.8-RS (short-reach) interfaces using CEI-28G (2m ≥ n)
Framer connected with m pluggable modules and/or ODSPs
*(*) NOTE – Some OPUCn tributary slots may be marked as unavailable*

m FOIC4.16-RS (short-reach) interfaces using CEI-28G (4m ≥ n)
Framer connected with m pluggable optics and/or ODSPs
*(*) NOTE – Some OPUCn tributary slots may be marked as unavailable*

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**Figure 8-4 – Application of FOIC2.8-RS and FOIC4.16-RS interfaces**

NOTE – The RS10 (544,514) FEC computing and 200G/400G FlexO-x-RS lane distribution is summarized in clause 9.2 and fully specified in clauses 12 and 13 of [ITU-T G.709.1]. For FOIC2.8-RS and FOIC4.16-RS, each physical lane corresponds to a 28G FOIC1.k-RS logical lane. This FEC scheme and lane architecture follows the same processes as specified in clause 119 of [b-IEEE 802.3] for 200GBASE-R (200GAUI-8) and 400GBASE-R (400GAUI-16) interfaces, respectively. Depending on the application, the RS10 FEC could be used as line FEC or terminated in an ODSP device. When the RS10 FEC is used as line FEC, the 28G lanes on the host interface could be bit multiplexed towards optical lanes. Also, in some applications, implementers could make use and or terminate the FlexO overhead in an ODSP device. Although some overhead may become optional, they are generated at the source and may be ignored at the sink (see Clause 9.1 and 9.2 for the handling of FlexO overhead for this type of application).

The bit rates of the FOIC2.8-RS and FOIC4.16-RS are indicated in Tables 8-4a and 8.4b.

**Table 8-4a – Bit rates of short-reach m*200G FlexO-2-RS-m and FOIC2.8-RS**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-2-RS-m | m × 8 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC2.8-RS | 8 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC2.8-RS lane | 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC2.8-RS lane bit rate is approximately: 27 952 368.611 kbit/s. | | |

**Table 8-4b – Bit rates of short-reach m*400G FlexO-4-RS-m and FOIC4.16-RS**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-4-RS-m | m × 16 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC4.16-RS | 16 × 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| FOIC4.16-RS lane | 256/241 × 239/226 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC4.16-RS lane bit rate is approximately: 27 952 368.611 kbit/s. | | |

## 8.5 OTL4.4-SC structure

As specified in clause 11 of [ITU-T G.709.2], an OTU4-SC signal can be adapted and carried over a 4-lane OTL4.4-SC interface. The OTU4-SC frame and FEC scheme are defined in clause 8 of [ITU-T G.709.2]. The frame format, overhead structure and FEC redundancy of OTU4-SC and

OTU4 are identical. Therefore, OTU4-SC is alike an OTU4 signal using strong Staircase FEC code (SC-FEC), instead of [ITU-T G.709] RS8 (255,239) code.

The OTL4.4-SC interface could be used to connect a 100G OTU4 framer implementing the hard-decision Staircase FEC with an optical line DSP (ODSP) device not supporting that FEC. This implementation enables the interoperable OTU4-SC metro/long reach interface per [ITU-T G.709.2], in which case the module has optical specifications with the parameters and optical modulation defined in [ITU-T G.698.2].

This particular application example of the OTL4.4-SC interface is illustrated in Figure 8-5.

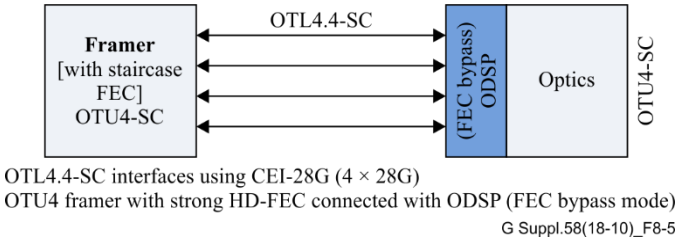



**Figure 8-5 – Example application of OTL4.4-SC interface**

Each OTL4.4-SC lane carries five bit-multiplexed logical lanes of an OTU4-SC as described in clause 11 of [ITU-T G.709.2] and Annex C of [ITU-T G.709].

The bit rates of the OTL4.4-SC are specified in [ITU-T G.709.2] indicated in Table 8-5.

**Table 8-5 – Bit rates of OTL4.4-SC**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL4.4-SC | 4 × 255/227 × 24 883 200 kbit/s | ±20 ppm |
| OTL4.4-SC lane | 255/227 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTL4.4-SC lane bit rate is approximately: 27 952 493.392 kbit/s. | | |

## 8.6 OTL50.2-RS and OTL50u.2-RS structures

As described in clause 9.6 of [ITU-T G.709.4], an OTU50-RS signal can be distributed (in groups of 10 bits) over two OTL50.2-RS lanes. The same scheme is used for OTU50u-RS signal distribution over two OTL50u.2-RS lanes.

NOTE – The RS (544, 514, 10) FEC scheme and lane distribution for OTU50-RS and OTU50u-RS signals per [ITU-T G.709.4], are the same as specified in clause 134 of [b-IEEE 802.3cd] for 50GBASE-R interface.

The OTL50.2-RS or OTL50.2u-RS interface could be used as a two-lane MFI in order to connect a 50G OTN framer with a 50G pluggable module supporting 25G electrical lanes on the host side and a 2:1 Mux.

Within the module, the 50G OTL50(u).1-RS transport lane is formed by simple bit-multiplexing of the two 25G OTL50(u).2-RS lanes from host side. It provides an interoperable optical interface format for OTU50-RS or OTU50u-RS short-reach interfaces.

The receive module bit-demultiplexes the 50G OTL50(u).1-RS transport lane recovered from the optical interface, into two 25G OTL50(u).2-RS electrical lanes on its host side towards the framer. The framer sink identifies each of the two 25G OTL50(u).2-RS lanes according to its AM specific pattern (unique UMx values). It must accept the two lanes in any position, and after alignment and deskew, interleave these two OTL50(u).2-RS logical lanes (in groups of 10-bits) into an OTU50(u)-RS frame.

Per Table 8-6b, the OTL50u.2-RS interface operates within 50GAUI-2 interface bit rate range and with similar FEC and lane format. There is just +15.6 ppm offset between the two nominal rates. So, first generation pluggable modules developed for Ethernet 50GBASE-R applications with 2:1 mux and 50GAUI-2 interface on host side could be reused for underclocked 50G OTN transport (i.e., OTU50u-RS) with an OTL50u.2-RS MFI between the framer and the optical module.

If such a module also supports full-rate 50G OTN signals with OTL50.2-RS MFI on its host side (i.e., 2×28G electrical lanes with almost same bit rate as FOIC1.4 lane and similar FEC and lane format as 50GAUI-2), it could also be reused for OTU50-RS full-rate transport.

Modules developed for [b-IEEE 802.3] are specified 50GBASE-LR and 50GBASE-ER with PAM4 optical PMD, and may be used for 50G OTU50(u)-RS interfaces when conforming to the optical specifications and parameters to be defined by application codes for metro networks. Some of these 50G modules may have a single WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These applications of OTL50.2-RS and OTL50u.2-RS interfaces (considering metro networks transport of OTU50-RS and OTU50u-RS) are illustrated in Figure 8-6.

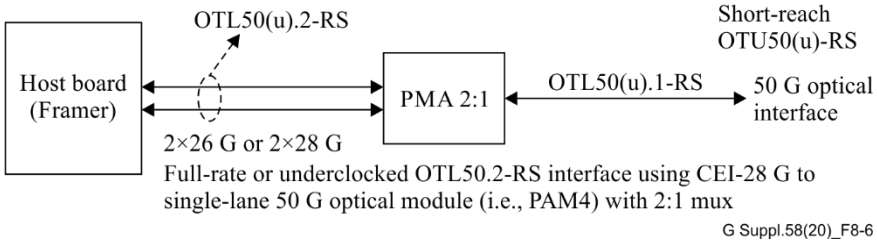



**Figure 8-6 – Example application of OTL50.2-RS and OTL50u.2-RS interfaces**

The bit rates of these full-rate (i.e., OTL50.2-RS) and underclocked (i.e., OTL50u.2-RS) interfaces and lanes are indicated in Tables 8-6a and 8-6b, per [ITU-T G.709.4] specifications.

**Table 8-6a – Bit rates of OTL50.2-RS**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL50.2-RS | 2 × 255/227 × 24 833 200 kbit/s | ±20 ppm |
| OTL50.2-RS lane | 255/227 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTL50.2-RS lane bit rate is approximately: 27 952 493.392 kbit/s. | | |

**Table 8-6b – Bit rates of OTL50u.2-RS**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL50u.2-RS | 2 × 680/637 × 24 833 200 kbit/s | ±20 ppm |
| OTL50u.2-RS lane | 680/637 × 24 833 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTL50u.2-RS lane bit rate is approximately: 26 562 913.658 kbit/s. | | |

## 8.7 OTU25-RS and OTU25u-RS structures

Clause 8.6 and Annex B of [ITU-T G.709.4] specify the interface formats of OTU25-RS and OTU25u-RS signals as single lane OTU25-RS and single lane OTU25u-RS, respectively.

NOTE – The RS (528, 514, 10) FEC scheme for OTU25u-RS per Annex B and C of [ITU-T G.709.4], is the same as that specified in clause 108 of [IEEE 802.3] for 25GBASE-R interface. The RS (544, 514, 10) FEC scheme for OTU25-RS per Annex A of [ITU-T G.709.4], is similar to the 50GBASE-R FEC.

The OTU25-RS or OTU25u-RS interface could be used as single-lane MFI in order to connect a 25G OTN framer with a 25G pluggable module.

These modules include a simple retimer and provide an interoperable optical interface format for OTU25-RS or OTU25u-RS short-reach interfaces.

Per Table 8-7b, the OTU25u-RS interface operates within 25GAUI interface bit rate range and with similar FEC and lane format. There is just +15.6 ppm offset between the two nominal rates. So, pluggable modules developed for Ethernet 25GBASE-R applications could be reused for underclocked 25G OTN transport (i.e., OTU25u-RS) with an OTU25u-RS MFI between the framer and the optical module.

If such a module also supports full-rate 25G OTN interface and OTU25-RS MFI on its host side (i.e., 28G electrical lane with same bit rate as OTL4.4 lane), it could also be reused for OTU25-RS full-rate transport.

Modules developed for [b-IEEE 802.3] are specified 25GBASE-LR and 25GBASE-ER, and may be used for 25G OTU25(u)-RS optical interfaces, when conforming to the optical specifications and parameters to be defined by application codes for metro networks. Some of these 25G modules may have a single WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These applications of OTU25-RS and OTU25u-RS interfaces (considering metro networks transport of OTU25-RS and OTU25u-RS) are illustrated in Figure 8-7.

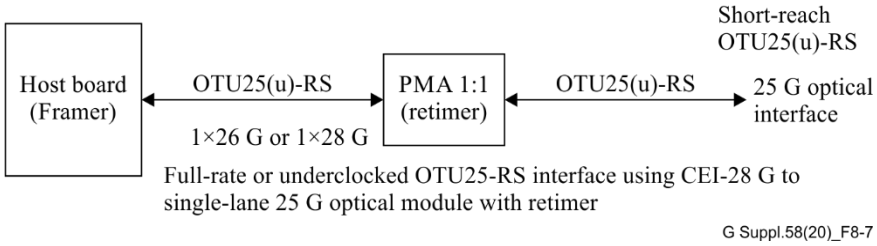



**Figure 8-7 – Example application of single-lane OTU25-RS and OTU25u-RS interfaces**

The bit rates of these full-rate (i.e., OTU25-RS) and underclocked (i.e., OTU25u-RS) interfaces and lanes are indicated in Tables 8-7a and 8-7b, per [ITU-T G.709.4] specifications.

**Table 8-7a – Bit rate of single-lane OTU25-RS**

| lane type | lane nominal bit rate | lane bit-rate tolerance |
|---|---|---|
| OTU25-RS lane | 255/227 × 24 883 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTU25-RS lane bit rate is approximately: 27 952 493.392 kbit/s. | | |

**Table 8-7b – Bit rate of single-lane OTU25u-RS**

| Lane type | lane nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTU25u-RS lane | 660/637 × 24 833 200 kbit/s | ±20 ppm |
| NOTE – The nominal OTU25u-RS lane bit rate is approximately: 25 781 651.491 kbit/s. | | |

## 9 Signal formats and rates carried over 53G or 56G electrical lanes

This clause describes some MFI structures using 56G physical lanes to carry 50G OTU50-RS or B100G OTUCn (n ≥ 1) signals, or using 53G single physical lane to carry underclocked

50G OTU50u-RS. The electrical characteristics of each 56G physical lane may comply with [b-OIF CEI-04.0] CEI-56G-*x*R-PAM4 specifications.

## 9.1 FOIC1.2-RS structure

As shown in Figures 7-1 and 10-1 of [ITU-T G.709.1], an OTUCn signal (n ≥ 1), full-rate or sub-rated (with some OPUCn tributary slots marked as unavailable), can be carried over n*FOIC1.2-RS bonded interfaces (short-reach FlexO-1-RS-n group, with x = 1 and k = 2). Each FOIC1.2-RS interface carry two physical lanes of a 100G FlexO-1-RS frame (carrying an OTUC).

An application example of the FOIC1.2-RS interface is to connect third generation beyond 100G OTN framers with ODSP devices over 56G electrical lanes and connecting these framers with emerging line side optical modules. See Figure 9-1.

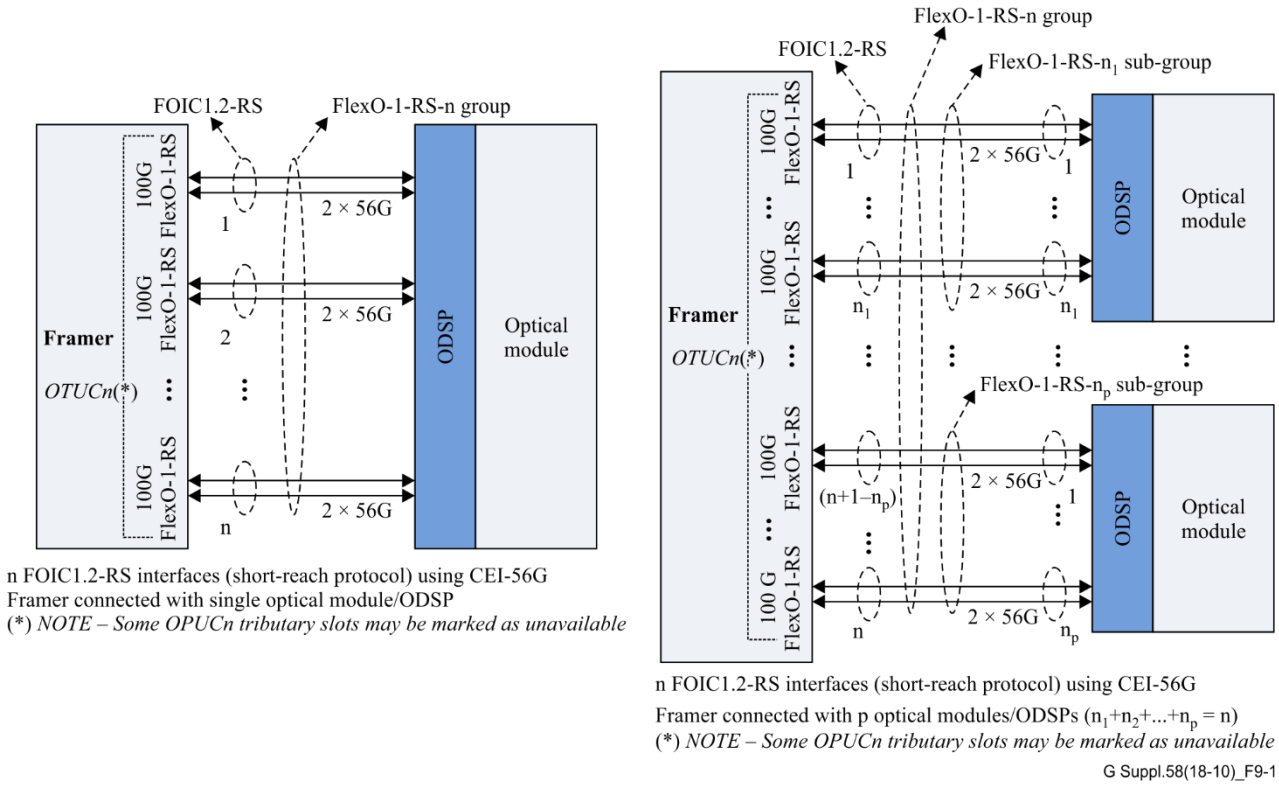



**Figure 9-1 – Example applications of a FOIC1.2-RS interface**

As per the mapping and framing specifications in clauses 10 and 11 of [ITU-T G.709.1] the OTUCn is split into n times OTUC, and each OTUC is synchronously mapped and carried into an individual 100G FlexO-SR frame. The 100G FlexO-1-RS frame consists of frame alignment markers (AM), overhead, FEC [RS10 (544,514) parity], and payload area in which the OTUC is transported (see clause 8 of [ITU-T G.709.1]).

Two possible application examples are considered. In the first case, the FlexO is terminated at both ends of the MFI. In the second case, the FlexO is terminated at the framer and [fully or partially] passed-through at the ODSP. The second case is for further study.

In the first application example, each 100G FlexO-1-RS frame is terminated at both end of the MFI.

Thus, some FlexO overhead area (OH) become optional and though they are generated at the source, they may be ignored at the sink.

The FlexO multi-frame alignment signal (MFAS) is generated at the source and fully interpreted at the sink per clause 9.2.1 of [ITU-T G.709.1].

The use of the OTN synchronization messaging channel (OSMC) and FlexO communications channel (FCC) overhead across the MFI is for further study.

Additionally, the Rx Line pre-FEC detected local degrade (LD) status bit is optionally carried in bit 8 of the STAT field.

The Rx ODSP detects the Rx line pre-FEC local degrade and forward the LD status bit to the Rx framer device through the MFI.

After synchronous scrambling and RS10 FEC parity insertion (see clauses 11.4 and 11.5 of [ITU-T G.709.1]), each individual 100G FlexO-1-RS frame is distributed (in group of 10-bits) on four 28G FOIC1.k-RS logical lanes as described for FOIC1.4-RS in clause 11.6.1 of [ITU-T G.709.1].

Each 56G physical lane of a FOIC1.2-RS is formed by simple bit-multiplexing of two 28G FOIC1.k-RS logical lanes from the same 100G FlexO-1-RS. At the sink, the bits from each individual 56G FOIC1.2-RS lane are deinterleaved into two 28G FOIC1.k-RS logical lanes. The sink will identify each of the four 28G FOIC1.k-RS logical lanes within a FOIC1.2-RS interface according to its AM specific pattern (unique UMx and UPx values). The sink must be able to accept the four 28G logical lanes in any position, and in addition to 28G logical lanes alignment and deskew, proceed to reorder these four 28G FOIC1.k-RS logical lanes prior to reassembly into a 100G FlexO-1-RS frame. Following this 100G FlexO-1-RS frame alignment, the FlexO overhead is terminated, and the OTUC is demapped and aligned. At the framer sink, the Rx line pre-FEC LD status bit is extracted from the FlexO overhead area and the n OTUC demapped from the n FOIC1.2 interfaces are deskewed to retrieve the original OTUCn signal. At the ODSP sink, $n_i$ OTUC demapped from $n_i$ FOIC1.2 interfaces could be deskewed, crunched (removing unavailable tributary slots), and assembled as the OTUC$n_i$ digital signal to be transmitted.

Groups of two FOIC1.2-RS physical lanes carrying one 100G FlexO-1-RS frame (so one OTUC instance) must be connected as a 100G group. Physical lanes within such a 100G group can be interchanged, but physical lanes of different 100G groups must not be interchanged.

The bit rates of FOIC1.2-RS are specified in Table 9-1.

**Table 9-1 – Bit rates of short-reach FlexO-1-RS-n and FOIC1.2-RS**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-1-RS-n | n × 2 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC1.2-RS | 2 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC1.2-RS lane | 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC1.2-RS lane bit rate is approximately: 55 904 737.223 kbit/s. | | |

## 9.2 FOIC2.4-RS and FOIC4.8-RS structures

As shown in Figure 7-1 of [ITU-T G.709.1], an OTUCn signal ($n \geq 1$), full-rate or sub-rated (with some OPUCn tributary slots marked as unavailable), can be carried over m*FOIC2.4-RS or m*FOIC4.8-RS bonded interfaces (short-reach FlexO-x-RS-m group, with {x,k} = {2,4} or {4,8} respectively). Each FOIC2.4-RS interface contains four physical lanes of a 200G FlexO-2-RS frame (carrying up to two OTUC). Each FOIC4.8-RS interface contains eight physical lanes of a 400G FlexO-4-RS frame (carrying up to four OTUC).

This provides interoperable modular short-reach OTN interfaces for B100G OTUCn ($n \geq 1$) transport signals, by bonding m * 200G or m * 400G standard-rate interfaces.

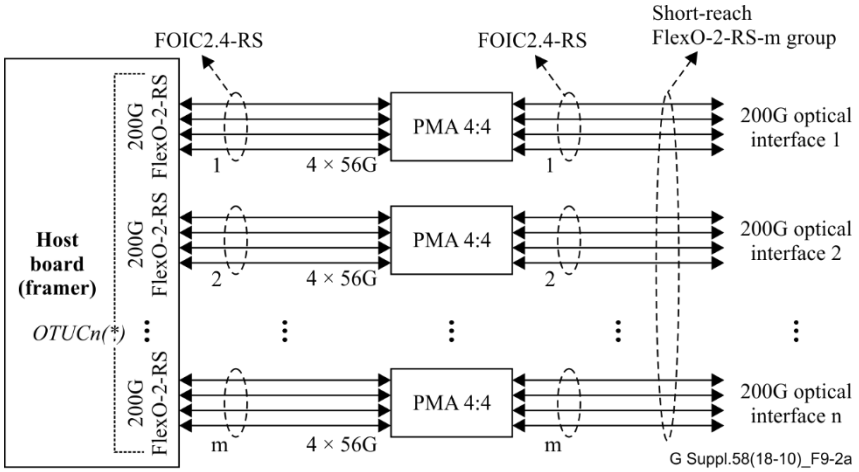
Four-lane pluggable modules developed for Ethernet 200GBASE-R applications and supporting the FlexO rate (that is ~ ½ the OTU4 rate per 56G lane) could be reused for 200G FlexO-2-RS

transport and FOIC2.4-RS interface. Eight-lane pluggable modules developed for Ethernet 400GBASE-R applications and supporting the FlexO rate (that is ~ ½ the OTU4 rate per 56G lane) could also be reused for 400G FlexO-4-RS transport and FOIC4.8-RS interface. Modules developed for [b-IEEE 802.3] specified 200GBASE-FR4, 200GBASE-LR4, 400GBASE-FR8 and 400GBASE-LR8.

They have corresponding optical specifications for 200G FlexO-2-RS and 400G FlexO-4-RS interfaces with the optical parameters as specified for the PAM4 application codes 4I1-4D1F and 8R1-4D1F or 8I1-4D1F, respectively, in [ITU-T G.959.1] and [ITU-T G.695] PAM4 application code C4S1-4D1F. The 200G modules have a four-lane WDM interface and the 400G modules have an eight-lane to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

Most of these pluggable modules use a four-lane electrical chip-to-module interface (200GAUI-4) or an eight-lane chip-to-module interface (400GAUI-8), whose specifications are found in Annex 120E of [b-IEEE 802.3].

These applications of m*FOIC2.4-RS bonded interfaces (short-reach m*200G FlexO-2-RS-m group) and m*FOIC4.8-RS bonded interfaces (short-reach m*400G FlexO-4-RS-m group are illustrated in Figures 9-2a and 9.2b respectively.




m FOIC2.4-RS short-reach interfaces using CEI-56G to m bonded 200G optical modules (2m ≥ n)
(*) *NOTE – Some OPUCn tributary slots may be marked as unavailable; if 2m = n, then each 200G FlexO-2-RS carries two OTUC; else if 2m > n, some 200G FlexO-2-RS signal frames within the group only carry one OTUC in their first 100G FlexO instance (second 100G FlexO instance being unequipped)*

**Figure 9-2a – FOIC2.4-RS interface main application example**

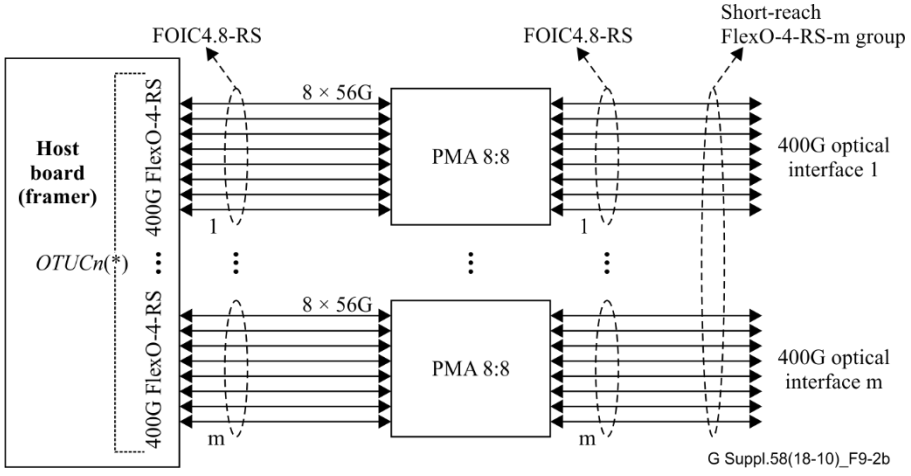
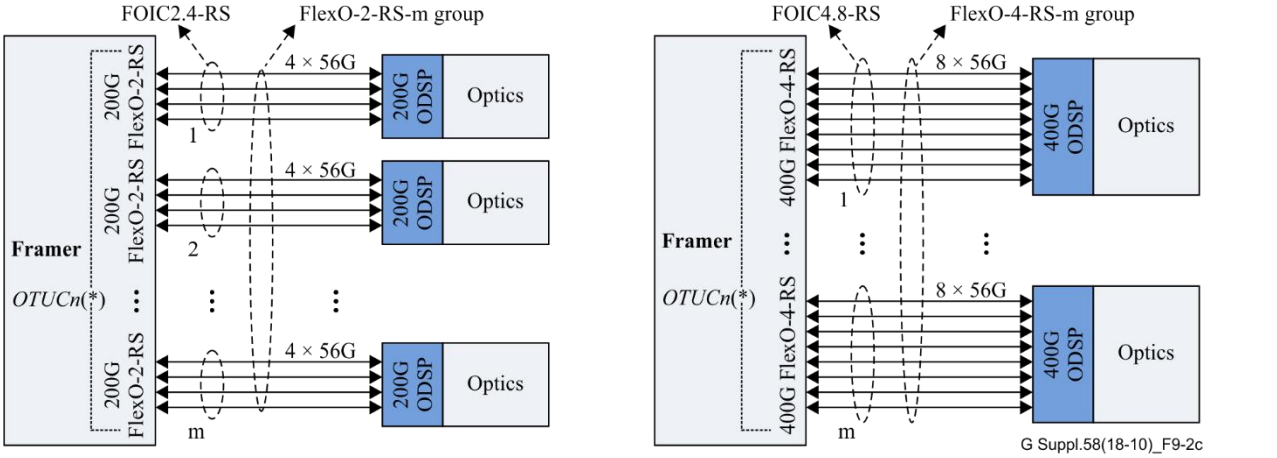



**Figure 9-2b – FOIC4.8-RS interface main application example**

The FOIC2.4-RS or FOIC4.8-RS interface could be used alternately to two or four FOIC1.4-RS interfaces to connect a beyond 100G OTN framer with one or more 200G or 400G ODSP devices supporting FlexO interfaces on the host side. One possible advantage for implementers is that the FEC and lane processing for 200G FOIC2.4-RS or 400G FOIC4.8-RS interface is almost identical to 200GAUI-4 or 400GAUI-8, respectively, thus allowing implementers to share digital logic in an optimized DSP supporting both Ethernet and OTN signals on its host side. This alternate application is illustrated in Figure 9-2c.




m FOIC2.4-RS interfaces using CEI-56G
Framer connected with m ODSPs (2m ≥ n)
(*) *NOTE – Some OPUCn tributary slots may be marked as unavailable*

m FOIC4.8-RS interfaces using CEI-56G
Framer connected with m ODSPs (4m ≥ n)
(*) *NOTE – Some OPUCn tributary slots may be marked as unavailable*

**Figure 9-2c – Alternate application of FOIC2.4-RS and FOIC4.8-RS interfaces**

As per the mapping specification in clause 10 of [ITU-T G.709.1] the OTUCn is split into n times OTUC, and each OTUC is synchronously mapped into an individual 100G FlexO instance/frame. Each 100G FlexO frame consists of frame alignment markers, pad area (PAD), overhead area, and payload area in which the OTUC is transported (see clause 8 of [ITU-T G.709.1]).

Then, as described in clause 12 of [ITU-T G.709.1] for 200G FlexO-2-RS, each set of two 100G FlexO instances with individual RS10 FEC parity area per instance (A, B) corresponds to a 200G FlexO-2-RS frame, and m* 200G FlexO-2-RS frames carry the OTUCn ($n \leq 2$ m). If [n = 2 m], then each 200G frame carry two OTUC. When [n < 2 m], then [i]* 200G frames carry two OTUC, while [m-i]* 200G frames only carry one OTUC in their first 100G FlexO instance (the second 100G FlexO instance being unequipped).

As described in clause 13 of [ITU-T G.709.1] for 400G FlexO-4-RS, each set of four 100G FlexO is interleaved (on a 10-bit basis) with RS10 FEC parity area per instance corresponds to a 400G FlexO-4-RS frame. m* 400G FlexO-4-RS frames carry the OTUCn. If [n = 4 m], then each 400G frame carry four OTUC. If [n < 4 m], then, some 400G frames carry fewer than four, but at least one OTUC [the last one, two or three 100G FlexO instance(s) being unequipped].

Depending on the application, the FlexO overhead may be terminated or carried transparently in the ODSP. When it is terminated in the ODSP, see clause 9.1 for the handling of FlexO overhead for this type of application.

For both applications, the Rx ODSP detects the Rx line pre-FEC Local Degrade (LD) and optionally forwards the LD status bit to the Rx framer device through the MFI, as carried in bit 8 of the STAT field of the first 100G FlexO instance overhead of the 200G or 400G FlexO-x-RS frame.

After interleaving (on a 10-bit basis) of the two 100G FlexO instances (200G FlexO-2-RS) or four 100G FlexO instances (400G FlexO-4-RS), FEC area insertion and scrambling of the 200G/400G FlexO-x-RS frame, the AM values are inserted. Then, the RS10 (544,514) FEC parity is calculated based on two interleaved RS10 codewords. For 200G FlexO-2-RS, the resulting 200G signal is

distributed on eight 28G FOIC2.k-RS logical lanes as per the 200G FOIC2.k-RS interface specifications in clause 12.6 of [ITU-T G.709.1]. For 400G FlexO-4-RS, the resulting 400G signal is distributed on sixteen 28G FOIC4.k-RS logical lanes as per the 400G FOIC4.k-RS interface specifications in clause 13.6 of [ITU-T G.709.1]. FEC calculation and lane distribution (in group of 10 bits) follow the same processes as specified in clause 119 of [b-IEEE 802.3] for 200GBASE-R and 400GBASE-R interfaces, respectively.

Each 56G physical lane of a FOIC2.4-RS or FOIC4.8-RS is formed by simple bit-multiplexing of two 28G logical lanes from the same 200G FlexO-2-RS or 400G FlexO-4-RS, respectively. At the sink, the bits from each individual 56G FOIC2.4-RS or 56G FOIC4.8-RS lane are deinterleaved into two 28G logical lanes. The sink will identify each of the eight 28G logical lanes within a FOIC2.4-RS interface according to its alignment marker specific pattern (unique UMx and UPx values). The sink must be able to accept the eight 28G logical lanes in any position, and in addition to 28G logical lanes alignment and deskew, proceed to reorder these eight 28G logical lanes prior to reassembly into a 200G FlexO-2-RS frame. Similarly, in the case of FOIC4.8-RS, the sink must be able to accept the 16 28G logical lanes in any position, and in addition to 28G logical lanes alignment and deskew, proceed to reorder these 16 28G logical lanes prior to reassembly into a 400G FlexO-4-RS frame.

Following this 200G or 400G FlexO-x-RS frame alignment, FEC termination and descrambling, the FlexO overhead is terminated, and, depending on the application, each OTUC can be demapped from its deinterleaved 100G FlexO instance and aligned. At the framer sink, the Rx line pre-FEC LD status bit is extracted from the FlexO overhead area and the n OTUC demapped from the m FOIC2.4-RS or m FOIC4.8-RS interfaces are deskewed to retrieve the original OTUCn signal. At the ODSP sink, and if applicable, n OTUC demapped from an FOIC2.4-RS or FOIC4.8-RS interface could be deskewed, crunched (removing unavailable tributary slots), and assembled as the OTUCn digital signal to be transmitted.

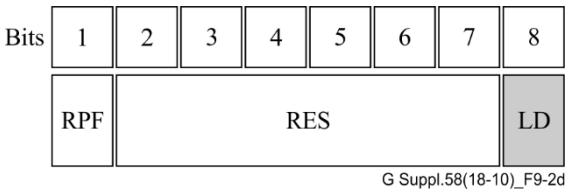



**Figure 9-2d – Optional Rx line pre-FEC local degrade (LD) status bit location in 1st instance of FlexO OH STAT field (Rx ODSP to framer direction)**

The bit rates of the FOIC2.4-RS and FOIC4.8-RS are specified in [ITU-T G.709.1] and indicated in Tables 9-2a and 9-2b, respectively.

**Table 9-2a – Bit rates of short-reach m*200G FlexO-2-RS-m and FOIC2.4-RS**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-2-RS-m | m × 4 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC2.4-RS | 4 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC2.4-RS lane | 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC2.4-RS lane bit rate is approximately: 55 904 737.223 kbit/s. | | |

**Table 9-2b – Bit rates of short-reach m*400G FlexO-4-RS-m and FOIC4.8**

| FOI type | FOI nominal bit rate | FOI bit-rate tolerance |
|---|---|---|
| FlexO-4-RS-m | m × 8 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC4.8-RSt | 8 × 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| FOIC4.8-RS lane | 256/241 × 239/226 × 49 766 400 kbit/s | ±20 ppm |
| NOTE – The nominal FOIC4.8-RS lane bit rate is approximately: 55 904 737.223 kbit/s. | | |

## 9.3 OTL50.1-RS and OTL50u.1-RS structures

As described in clause 9.6 of [ITU-T G.709.4] an OTU50-RS signal can be distributed (in groups of 10-bits) over two OTL50.2-RS logical lanes, that can be bit-multiplexed into a single OTL50.1-RS lane. The same scheme is used to adapt an OTU50u-RS signal into an OTL50u.1-RS lane.

NOTE – The RS (544, 514, 10) FEC scheme and lane distribution for OTU50-RS and OTU50u-RS signals per [ITU-T G.709.4], are the same as specified in clause 134 of [IEEE 802.3cd] for 50GBASE-R interface.

The OTL50.1-RS or OTL50u.1-RS interface could be used as single-lane MFI in order to connect a 50G OTN framer with a 50G pluggable module supporting a 50G electrical lane on its host side.

These modules include a simple retimer and provide an interoperable optical interface format for OTU50-RS or OTU50u-RS short-reach interfaces.

The framer sink bit-demultiplexes the 50G OTL50(u).1-RS electrical lane (MFI received from the module) into two 25G OTL50(u).2-RS logical lanes and identifies each of the two logical lanes according to its AM specific pattern (unique UMx values). After alignment and deskew, these two OTL50(u).2-RS logical lanes are interleaved (in groups of 10-bits) into an OTU50(u)-RS frame.

Per Table 9-3b, the OTL50u.1-RS interface operates within 50GAUI-1 interface bit rate range and with similar lane and FEC format. There is just +15.6 ppm offset between the two nominal rates. So, second generation pluggable modules developed for Ethernet 50GBASE-R applications with simple retimer and 50GAUI-1 interface on the host side could be reused for underclocked 50G OTN signal transport (i.e., OTU50u-RS) with an OTL50u.1-RS MFI between the framer and the optical module.

If such a module also supports a full-rate 50G OTN interface with single-lane OTL50.1-RS MFI on its host side (i.e., 56G electrical lane with almost same bit rate as FOIC1.2 lane and similar FEC and lane format as 50GAUI-1), it could also be reused for OTU50-RS full-rate transport.

Modules developed for [b-IEEE 802.3] are specified 50GBASE-LR and 50GBASE-ER with PAM4 optical PMD, and may be used for 50G OTU50(u)-RS interfaces when conforming to the optical specifications and parameters to be defined by application codes for metro networks. Some of these 50G modules may have a single WDM interface to and from a transmit/receive pair of [ITU-T G.652] optical fibres.

These applications of OTL50.1-RS and OTL50u.1-RS interfaces (considering metro networks transport of OTU50-RS and OTU50u-RS) are illustrated in Figure 9-3.

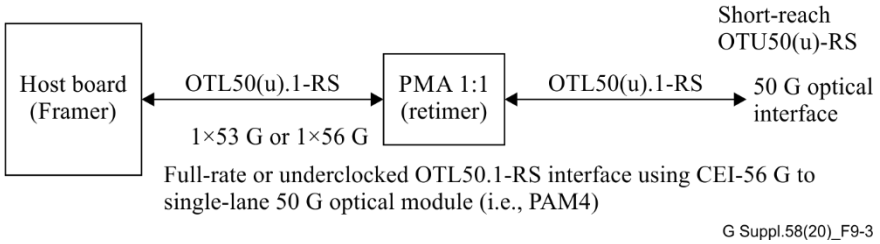



**Figure 9-3 – Example application of single-lane OTL50.1-RS and OTL50u.1-RS interfaces**

The bit rates of these full-rate (i.e., OTL50.1-RS) and underclocked (i.e., OTL50u.1-RS) interfaces and lanes are indicated in Table 9-3a and 9-3b, per [ITU-T G.709.4] specifications.

**Table 9-3a – Bit rates of single-lane OTL50.1-RS**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL50.1-RS | 1 × 255/227 × 49 766 400 kbit/s | ±20 ppm |
| OTL50.1-RS lane | 255/227 × 49 766 400 kbit/s | ±20 ppm |
| NOTE – The nominal OTL50.1-RS lane bit rate is approximately: 55 904 986.784 kbit/s. | | |

**Table 9-3b – Bit rates of single-lane OTL50u.1-RS**

| OTL type | OTL nominal bit rate | OTL bit-rate tolerance |
|---|---|---|
| OTL50u.1-RS | 1 × 680/637 × 49 766 400 kbit/s | ±20 ppm |
| OTL50u.1-RS lane | 680/637 × 49 766 400 kbit/s | ±20 ppm |
| NOTE – The nominal OTL50u.1-RS lane bit rate is approximately: 53 125 827.316 kbit/s. | | |

# Bibliography


[b-IEEE 802.3] IEEE Std. 802.3 (2018), *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*.

[b-IEEE 802.3cd] IEEE Std 802.3cd-2018, *IEEE Standard for Ethernet Amendment 3: Media Access Control Parameters for 50 Gb/s and Physical Layers and Management Parameters for 50 Gb/s, 100 Gb/s, and 200 Gb/s*.

[b-OIF CEI-04.0] Optical Internetworking Forum Implementation Agreement OIF-CEI-04.0 (2017), *Common Electrical I/O (CEI) – Electrical and Jitter Interoperability agreements for 6G+ bps, 11G+ bps,25G+ bps and 56G+ bps I/O*.

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