Implementation Agreement for Integrated Polarization Multiplexed Quadrature Modulated Transmitters for Metro Applications

IA # OIF-PMQ-MTX-01.0

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TITLE: **Implementation Agreement for Integrated Polarization Multiplexed Quadrature Modulated Transmitters for Metro Applications**

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ABSTRACT: This Implementation Agreement specifies key aspects of integrated polarization multiplexed quadrature modulated optical transmitters operating at rates up to 32 GBd for applications such as 100G PM-QPSK DWDM transmission. This is not a multi-source agreement (MSA) but it is expected that it will serve as a foundation for future MSAs.

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4 Document Revision History

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5 Introduction

This document details an Implementation Agreement (IA) for an optical integrated Polarization Multiplexed (PM) quadrature modulated transmitter for applications with nominal symbol rates of up 32 GBaud. While specifically addressing 100G PM-QPSK applications with FEC, this Implementation Agreement strives to remain modulation format and data rate agnostic whenever practical to maximize applicability to other future applications. This IA is expected to serve as a foundation for future MSAs.

6 Functionality

This Implementation Agreement specifies in detail a single opto-electronic module with the functionality contained in the yellow area enclosed by the bold line in Figure 1. This module will be referred to as Polarization Multiplexed-Quadrature Modulator or PM-Q Modulator.

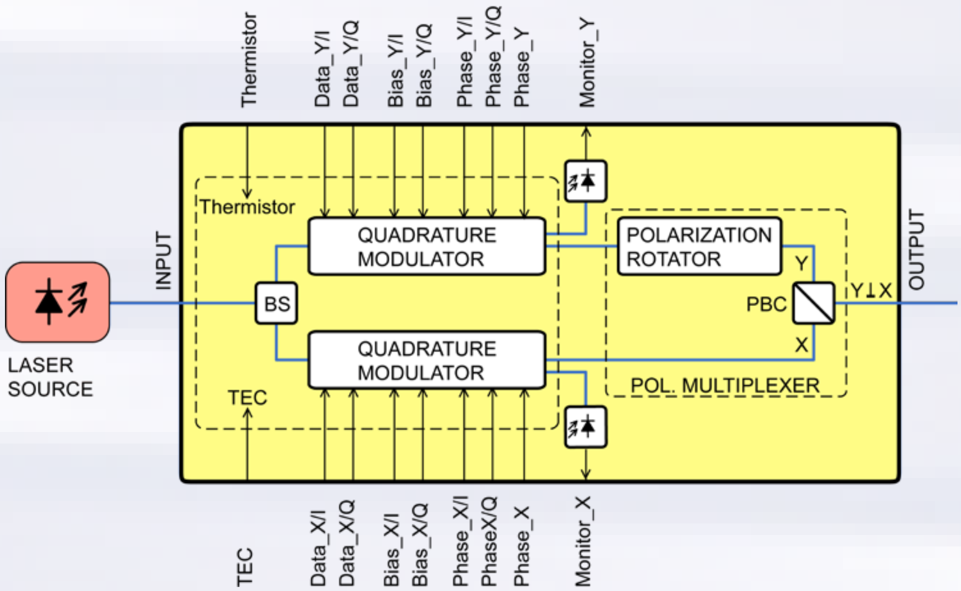

Figure 1 Functional diagram of a polarization multiplexed quadrature modulated integrated transmitter with a detailed functional diagram of the data modulator.

The optical power from an input fiber is divided into two parts and each part is independently modulated by a quadrature modulator. The resulting two modulated signals are combined with their polarizations orthogonal to each other, and output through an optical output fiber. The power in each of the two polarizations is independently monitored with photodiodes.

The quadrature modulators typically comprise two nested Mach-Zehnder modulators with bias control, a 90º phase shifter in the outer modulators with phase control, and an output power monitoring output. Any implementation or technology choices may be used to realize the same basic functionality.

As indicated in Figure 1, the PM-Q Modulator includes the following basic functional components:

- One optical input
- One optical power splitter
- Two independent quadrature modulators
- Two independent monitoring photodiodes
- One polarization multiplexer
- One optical output

The PM-Q Modulator module specified in this Implementation Agreement does not include drivers or any control electronics.

The following independent interfaces are specified for the PM-Q modulator:

- One optical input fiber
- One optical output fiber
- Eight high-speed data interfaces (differential option, 4 tributaries) or
Four high-speed data interfaces (single-ended option, 4 tributaries)
- Eight modulator DC bias control interfaces (differential option, via integrated bias tee) or
Four modulator DC bias control interfaces (single-ended option)
- Twelve phase control interfaces (eight child; four parent)
- Two power monitoring interfaces
- One thermistor
- One thermo-electric cooler (TEC)

The two polarized components at the output are referred to as “X” and “Y”, and the arms in which information is modulated onto the polarization component are correspondingly referred to as X and Y arms. Each quadrature modulator is driven by an “I” and a “Q” data signal. The four high-speed data interfaces are referred to as X/I, X/Q, Y/I and Y/Q data interfaces. Nominal phase shifts in the quadrature modulators between I and Q shall be the same in X and Y arms.

Each of the four data modulators needs to be biased with a suitable DC voltage. This IA specifies biasing pins supporting both single-ended as well as push-pull biasing. The naming of the bias pins is consistent with the naming of the high-speed data interfaces. The I and Q phase offset is controlled via phase control pins also supporting both single-ended as well as push-pull control. The phase offset between I and Q in X and Y arms is controlled by phase control interfaces X Phase and Y Phase respectively.

7 Module Mechanical Specification

Figure 2 defines the location of the Datum D0, relative positions of low-speed and high-speed interfaces, and dimensions which are specified in Table 1. Boot lengths are not specified. Mounting holes shall be of type M2.

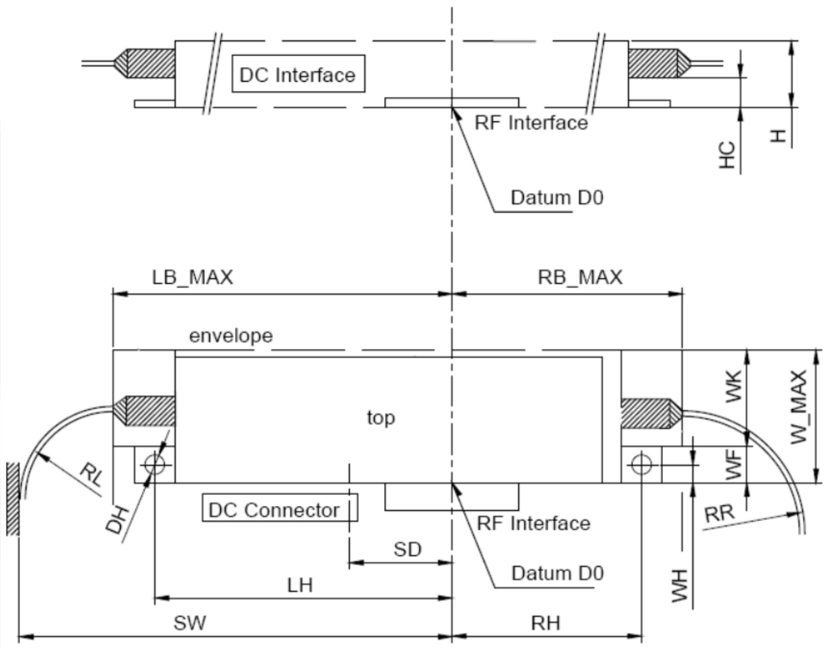

Figure 2 Location of Datum, interfaces, and definition of dimensions.

Table 1 Features and dimensions in mm.

Parameter	Feature or Dimension			Remarks
	Min	Typ	Max	
Input fiber side wall	right			
Output fiber side wall	left			
Mounting hole	flange			Screw-down type
LB_MAX 1)			34	
RB_MAX 1)			26	
W_MAX 1)			12	
H			6.5	
RL		15		
RR		15		
SD		12		
SW			49	
HC	1.2			Clearance area
WK			(W-WF)	Boot area
WF	3.8			
LH		24.8		
RH		17.7		
WH		2		
DH	2.2	2.3	2.4	Diameter for mounting holes for M2 screws
1) Smaller values within this envelope are allowed for smaller modules				

8 Electrical Interface Specifications

8.1 Mechanical Specification of Low-Speed Interface

The low-speed interface shall connect via a FPC and FPC connector to the host board. Dimensions of the FPC end, location of the connector, and informative example connector are shown in Figures 3, 4, and 5. The length of the FPC and height in Figure 4 are minimum values. The connector is qualified based on MIL-STD-202.

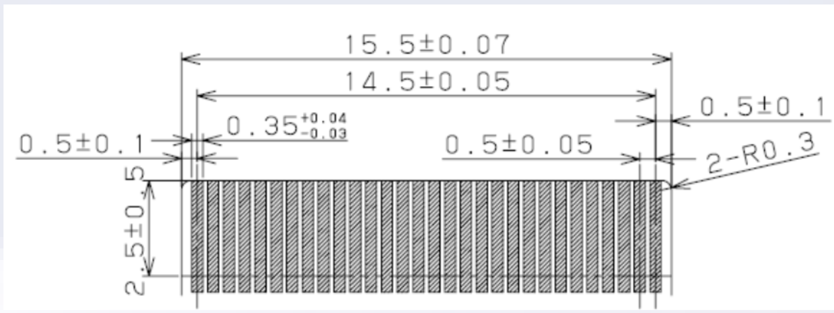

Figure 3 Dimensions of FPC cable end.

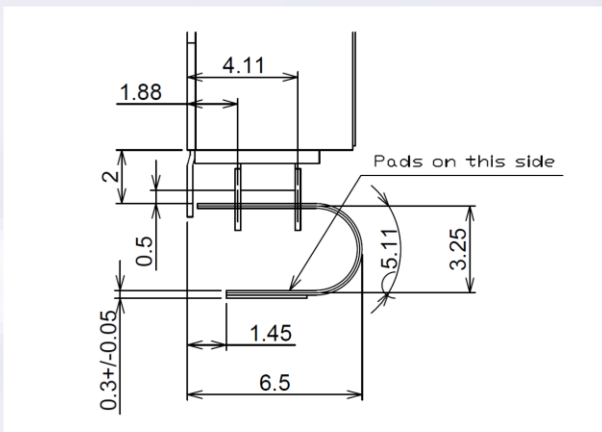

Figure 4 Dimensions of FPC and FPC attachment to module.

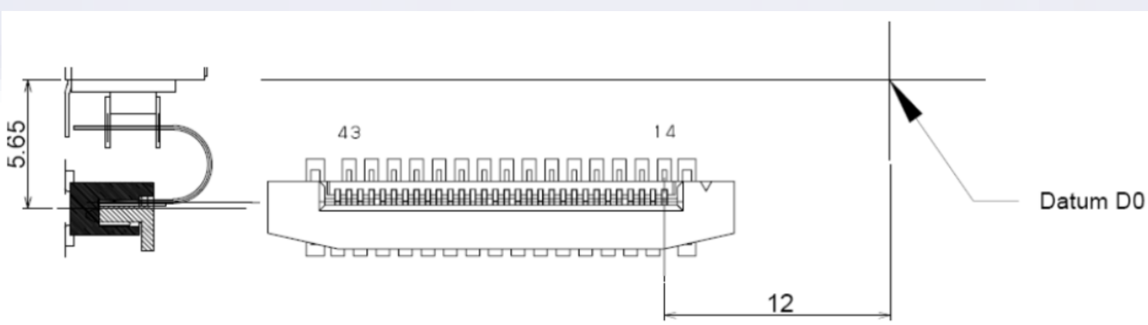

Figure 5 Relative placement of connector on host board, and informative example connector Molex 52559-3079.

8.2 Mechanical Specification of High-Speed Interface

Figures 6 and 7 define dimensions of the high-speed interface options.

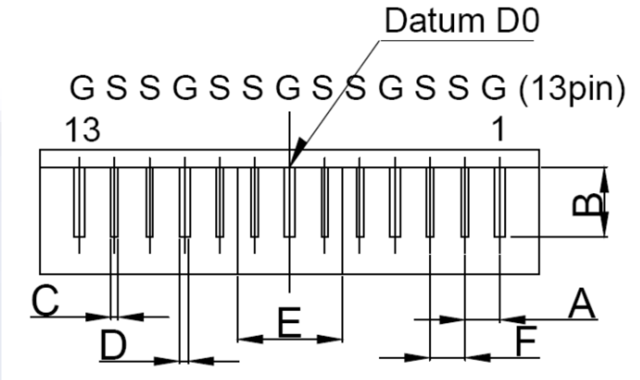

Figure 6 Mechanical specification of the differential high-speed (RF) interface option (top view).

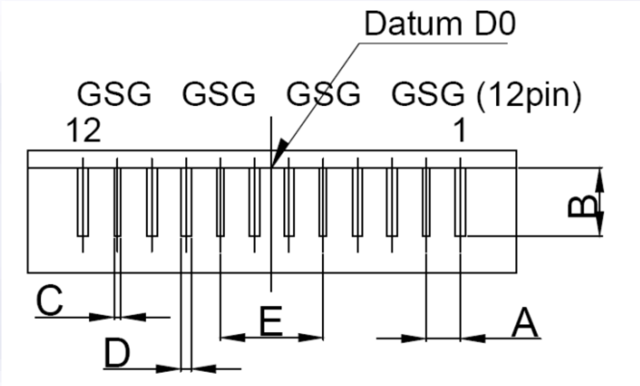

Figure 7 Mechanical specification of the single-ended high-speed (RF) interface SMT option (top view).

The pin numbering starts with the first RF pin furthest from the low-speed interface.

Table 2 High-speed electrical interface dimensions in mm.

Parameter	Symbol	Feature or Dimension		
		Min	Typ	Max
Lead Pitch	A		1.0	
Lead Length	B	1.5		3.0
Signal Lead Width	C	0.1		0.3
Ground Lead Width	D	0.1		0.5
Channel Pitch	E		3.0	
Signal to Complementary Signal Pitch	F		1.0	

8.3 Electrical Interface pin-out

Table 3 Electrical interface pin-out for differential-drive modulators.

Pin	Symbol	Description
1	GND	Ground
2	Data_X/I(p)	Data I for X polarization
3	Data_X/I(n)	Data I for X polarization
4	GND	Ground
5	Data_X/Q(p)	Data Q for X polarization
6	Data_X/Q(n)	Data Q for X polarization
7	GND	Ground
8	Data_Y/I(p)	Data I for Y polarization
9	Data_Y/I(n)	Data I for Y polarization
10	GND	Ground
11	Data_Y/Q(p)	Data Q for Y polarization
12	Data_Y/Q(n)	Data Q for Y polarization
13	GND	Ground
14	Thermistor-	Thermistor-
15	Thermistor+	Thermistor+
16	TEC-	TEC-
17	TEC-	TEC-
18	TEC+	TEC+
19	TEC+	TEC+
20	Phase_X/I(p)	Phase Control for I, X, p
21	Phase_X/I(n)	Phase Control for I, X, n
22	Phase_X/Q(p)	Phase Control for Q, X, p
23	Phase_X/Q(n)	Phase Control for Q, X, n
24	Phase_X(p)	Phase Control for X, p
25	Phase_X(n)	Phase Control for X, n
26	Phase_Y/I(p)	Phase Control for I, Y, p
27	Phase_Y/I(n)	Phase Control for I, Y, n
28	Phase_Y/Q(p)	Phase Control for Q, Y, p
29	Phase_Y/Q(n)	Phase Control for Q, Y, n
30	Phase_Y(p)	Phase Control for Y, p
31	Phase_Y(n)	Phase Control for Y, n
32	GND	Ground
33	MPD-A-X	Monitor PD Anode for X
34	MPD-K (X/Y)	Monitor PD Cathode for X and Y
35	MPD-A-Y	Monitor PD Anode for Y
36	Bias_X/I(p)	DC Bias for I, X, p
37	Bias_X/I(n)	DC Bias for I, X, n
38	Bias_X/Q(p)	DC Bias for Q, X, p
39	Bias_X/Q(n)	DC Bias for Q, X, n
40	Bias_Y/I(p)	DC Bias for I, Y, p
41	Bias_Y/I(n)	DC Bias for I, Y, n
42	Bias_Y/Q(p)	DC Bias for Q, Y, p
43	Bias_Y/Q(n)	DC Bias for Q, Y, n

TEC pins of same polarity are paired to give suitable current carrying capacity.

Table 4 Electrical interface pin-out for single-ended drive modulators.

Pin	Symbol	Description
1	GND	Ground
2	Data_X/I	Data I for X polarization
3	GND	Ground
4	GND	Ground
5	Data_X/Q	Data Q for X polarization
6	GND	Ground
7	GND	Ground
8	Data_Y/I	Data I for Y polarization
9	GND	Ground
10	GND	Ground
11	Data_Y/Q	Data Q for Y polarization
12	GND	Ground
13	--	Not Present
14	NC	Not Connected
15	NC	Not Connected
16	NC	Not Connected
17	NC	Not Connected
18	Phase_X/I(p)	Phase Control for I, X, p
19	Phase_X/I(n)	Phase Control for I, X, n
20	Phase_X/Q(p)	Phase Control for Q, X, p
21	Phase_X/Q(n)	Phase Control for Q, X, n
22	Phase_X(p)	Phase Control for X, p
23	Phase_X(n)	Phase Control for X, n
24	Phase_Y/I(p)	Phase Control for I, Y, p
25	Phase_Y/I(n)	Phase Control for I, Y, n
26	Phase_Y/Q(p)	Phase Control for Q, Y, p
27	Phase_Y/Q(n)	Phase Control for Q, Y, n
28	Phase_Y(p)	Phase Control for Y, p
29	Phase_Y(n)	Phase Control for Y, n
30	GND	Ground
31	MPD-A-X	Monitor PD Anode for X
32	MPD-K (X/Y)	Monitor PD Cathode for X and Y
33	MPD-A-Y	Monitor PD Anode for Y
34	Bias_X/I	DC Bias for I, X
35	Bias_X/Q	DC Bias for Q, X
36	Bias_Y/I	DC Bias for I, Y
37	Bias_Y/Q	DC Bias for Q, Y
38	TH1	Thermistor1
39	TH2	Thermistor2
40	TEC-	TEC-
41	TEC-	TEC-
42	TEC+	TEC+
43	TEC+	TEC+

TEC pins of same polarity are paired to give suitable current carrying capacity.

9 Electrical Properties

9.1 Low-Speed Electrical Interface Properties

The electrical properties related to the power monitor diodes, temperature monitor and TEC are specified in Table 5. TEC Voltage and TEC Current ranges are provided for circuit design. The product of the actual values shall be limited to satisfy the TEC Power Dissipation specification. The opto-electronic properties of the optical modulator including the high-speed data interface are specified in Section 10.

Table 5 Low-speed electrical interface properties.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Monitor PD Responsivity	mA/W	1)		1)	
Monitoring PD O/E Bandwidth	GHz	1			
Thermistor Resistance	kOhm		10		At 25 ºC
Thermistor Beta value	K		3930		25 ºC / 50 ºC
TEC Voltage	V	-3.0		3.0	Tc 2) =-5 to 75 ºC
TEC Current	A	-0.7		0.7	
TEC Power Dissipation	W			1.5	

1) Application specific. Due to the range of applications for this component, a single specific value cannot be provided.
2) Tc is the temperature at the TEC heat dissipating wall (bottom) of the module package.

9.2 Internal Bias Tee Specification

This section only applies to the case of the differential drive option.

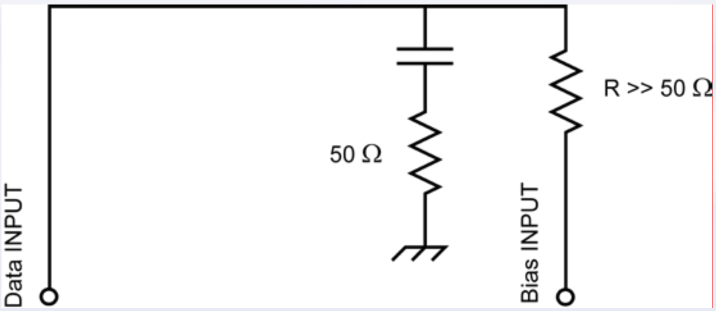

Figure 8 Internal bias tee configuration for the differential option.

10 Opto-Electronic Properties

Electrical specification of the high-speed interface and opto-electronic properties are given in Table 6 at the end of life over the operating temperature and frequency ranges.

Table 6 Electrical and opto-electronic properties.

Parameter	Unit	Min.	Typ.	Max.	Remarks
S21 E/O Bandwidth (3dB)	GHz	20			3% smoothed, reference frequency at 1.5 GHz
S11 Electrical Return Loss f ≤ 25 GHz 25 < f ≤ 32 GHz	dB	 10 8			
Vpi_PRBS	V			2.5	Specified at PRBS31 at 32 GBd and over DC bias control range: -1.5…-15 V
Vpi_LF	V			2.5	Measured at 1.5 GHz
RF Impedance	Ohm		50		
I/Q skew [1)]	ps			4	For each polarization component and for each tributary
Total skew [2)]	ps			10	
I/Q skew variation	ps			2	Over operating temperature and lifetime
Total skew variation	ps			5	Over operating temperature and lifetime

1) I/Q Skew is the skew between channel pairs X/I and X/Q, and Y/I and Y/Q.
2) Total skew is the maximum skew between any of the four physical channels X/I, X/Q, Y/I and Y/Q.

Skew is defined as the maximum signal propagation time difference between physical signal channels, between electrical input and optical output interfaces. Skew includes any skew variation due to aging, temperature and any other effects. Skew variation is defined as the absolute value of the deviation over time from certain initial skew amount at 25ºC and begin-of-life (BOL).

11 Optical Properties

Optical properties of the optical modulator are listed in Table 7 at the end of life over the operating temperature and frequency ranges.

Table 7 Optical properties.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Operating Frequency C-Band	THz	191.35		196.2	
Input power	dBm			18	Peak power
Insertion loss	dB	1)		17	All modulators at peak transmission, for each polarization
Insertion loss difference between X and Y				1)	
Optical return loss	dB	30			Input and output
Parent MZI ER	dB	18			
Child MZI ER	dB	18			
Polarization ER	dB	20			
1) Application specific. Due to the range of applications for this component, a single specific value cannot be provided.					

In case of polarization maintaining fiber, the optical connector key shall be aligned to the slow axis of the polarization maintaining fiber. The input fiber shall be polarization maintaining. Optical and opto-electronic specifications assume that a polarized input signal is launched into the slow axis of the input fiber.

The output fiber shall be either SMF or PMF.

12 Thermal Properties

The typically expected operating temperature range is -5ºC to +75ºC.

Table 8 Environmental Conditions.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Operating Temperature Range	ºC	-5		75	

Appendix A: Glossary

AC	Alternating Current
BS	Beam Splitter
BW	Band Width
DC	Direct Current
E/O	Electro-Optical
ER	Extinction Ratio
FEC	Forward Error Correction
FIT	Failures In Time
GND	Ground
IA	Implementation Agreement
MSA	Multi-Source Agreement
MZI	Mach-Zehnder Interferometer
NC	Not Connected
PBC	Polarization Beam Combiner
PD	Photo Diode
PMF	Polarization Maintaining Fiber
PM-Q	Polarization Multiplexed Quadrature
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SMF	Single Mode Fiber
TEC	Thermo-Electric Cooler

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