Gigabit Ethernet over Plastic Optical Fibre (POF) Specifications

Specifications for Automotive Ethernet

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<Abstract>
The 1000BASE-RHC Physical Layer (PHY) specifications and management parameters for point-to-point full duplex 1Gb/s operation over plastic optical fibre (POF) are defined by IEEE802.3bv.
This document provides supplemental specifications for automotive applications. The test specifications for the POFs, connectors and wire harnesses are also specified by this document.

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1 Introduction

In order to penetrate 1000BASE-RHC (Gigabit Ethernet over Plastic Optical Fibre) that has been standardized in IEEE802.3 in the automotive applications, the ISO standardization activities have started in the ISO TC22 SC31 / SC32. However, the standard 1000BASE-RHC does not specify the respective components and vehicle-specific functions in the system so that the addition of specification items is required for the use of the automotive applications. This document shall provide the automotive requirements for 1000BASE-RHC to support the ISO standardization activities.

1.1 References

IEC 60793-1-20: Measurement methods and test procedures – Fibre geometry

IEC 60793-1-40: Measurement methods and test procedures - Attenuation

IEC 60793-1-43: Measurement methods and test procedures -Numerical aperture measurement

IEC 60793-1-47: Measurement methods and test procedures - Macrobending loss

IEC 60793-1-51: Measurement methods and test procedures - Dry heat (steady state) tests

IEC 60793-2-40: Product specifications - Sectional specification for category A4 multimode fibres

IEC 60794-1-21: Generic specification - Basic optical cable test procedures - Mechanical tests methods

IEC 60794-2-41: Indoor cables - Product specifications for simplex and duplex buffered A4 fibres

IEC 61300-3-53: Examinations and measurements - Encircled angular flux (EAF) measurement method based on two-dimensional far field data from step index multimode waveguide (including fibre)

ISO 8092-2: Definitions, test methods and general performance requirements

1.2 List of abbreviations and glossary of terms

DUT	Device Under Test
ECU	Electronic Control Unit
FOT	Fibre Optic Transceiver
FFP	Far Field Pattern
MDIO	Management Data Input/ Output
NA	Numerical Aperture
OEM	Original Equipment Manufacturing
PCS	Physical Coding Sublayer
PMA	Physical Medium Attachment sublayer
PMD	Physical Medium Dependent sublayer
PMMA	Poly-methyl methacrylate
POF	Plastic Optical Fibre
POF cable	jacketed POF
POF-end	end surface of POF cable
SNR	Signal-Noise Ratio

W/H Wire Harness

1.3 Scope

The specifications shall define the scope of 1000BASE-RHC used automotive Gigabit Ethernet system and the components in the system. Nevertheless, the items specified by 1000BASE-RHC are excluded from the scope.

The objectives of this document are:

a) Select the requirements to use 1000BASE-RHC in the automotive environment.
b) Specify the mechanical characteristics required for the components.
c) Specify the mechanical characteristics testing method for the components.
d) Specify the electrical characteristics that are not specified by 1000BASE-RHC.
e) Specify specifications of the interface that are not specified by 1000BASE-RHC.
f) Noise characteristics are not specified.

1.4 Relationship to IEEE802.3bv specification

The IEEE802.3bv specification does not define the scope of mechanical characteristics of the components in the optical transmission system and electrical characteristics and functions of each interface. Therefore, the requirements for the use of the IEEE802.3bv technology in the automotive environment IEEE802.3bv defined in this specification can be regarded as a supplement to the IEEE802.3bv specification.

1.5 Definitions

1.5.1 GEPOF communication system model

The GEPOF communication system model is shown in Figure 1.6.1a.

The scope of this document is specified in a red-dotted frame.

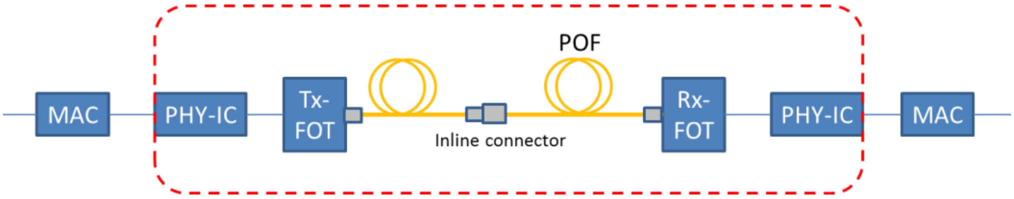

Figure 1.6.1a – Schematic diagram of GEPOF communication system

1.5.2 Fibre optic cabling model

The fibre optic cabling model is shown in Figure 1.6.2a and 1.6.2b.

(1) 15 m with 4 inline connections

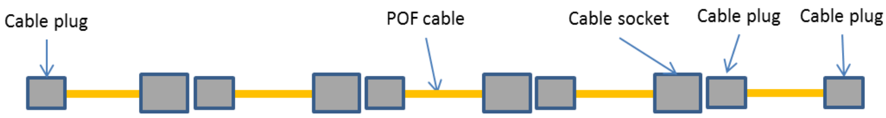

Figure 1.6.2a – Schematic diagram of 15m with 4 inline connections

(2) 40 m without inline connection

Figure 1.6.2b - Schematic diagram of 40m without inline connection

1.5.3 Requirements of optical components

The optical components shall meet the following requirements. The POF cable must function within the automotive environment with the following minimum to maximum temperature ranges:

Table 1.6.3a – Requirements of optical components

Clause	Parameter	Criteria	Note
	POF/POF cable		
2.1.1	Core diameter	980 µm ± 45 µm	IEC 60793-1-20 IEC 60793-2-40
	Cladding diameter	1000 µm ± 45 µm	
	Jacket diameter	2.3mm(Informative)	
2.1.2	Numerical aperture	0.55 ± 0.05	IEC 60793-1-43 IEC 60793-2-40 IEC 61300-3-53
2.1.3	Attenuation	< 0.17 dB/m	IEC 60793-1-40 IEC 60793-2-40
2.1.4	Storage temperature	- 40 °C to + 105 °C	IEC 60793-1-51
2.1.5	Ambient temperature	- 40 °C to + 105 °C	IEC 60793-1-51
2.1.6	Minimum bending radius(temporary)	10 mm	IEC 60793-1-47
2.1.7	Minimum bending radius(permanently)	25 mm	IEC 60793-1-47
2.1.8	Minimum tensile strength	60 N	IEC 60794-1-21 IEC 60794-2-41
	Connector		
2.2.2	Storage temperature	- 40 °C to 105 °C	ISO 8092-2 EIA/TIA 455-13A
2.2.3	Maximum coupling loss	1.5 dB	EIA/TIA 455-34A
2.2.4	Minimum lock strength	100 N	ISO 8092 ANSI/EIA 364-13
2.2.5	Minimum cable holding force	110 N	EIA 364-38A-83
2.2.6	Maximum mating force	45 N	ISO 8092-2 Part.4.3 ANSI/EIA 364-13
2.2.7	Mating tolerance	10 times	OEMs

2 Mechanical/Optical characteristics

2.1 Mechanical/Optical characteristics for POF

The POF specified by IEEE802.3bv shall be used.

2.1.1 Attenuation

(1) Purpose

The performance of attenuation strongly affects the system margin.

The optical penetration characteristic of the plastic optical fibre is shown in the above figure and changes depending on the wavelength of light source. 1000BASE-RHC uses 650 nm-band.

(2) Procedure

1. A 50 m POF cable is connected to a light source with a centre wavelength of 650 nm and a spectrum analyser, and the attenuation is measured. .
2. The POF cable is cut at 40 m from the output of POF-end and the spectrum analyser is connected. The light source is not disconnected from the POF cable attenuation of the 10 m POF cable is measured.
3. The attenuation of 40 m POF cable is calculated based on the measurement results at 50 m and 10 m.

(3) Requirements

Attenuation ≥ 170 dB/km @ 650 nm

(4) Related standards

IEC 60793-1-40
IEC 60793-2-40

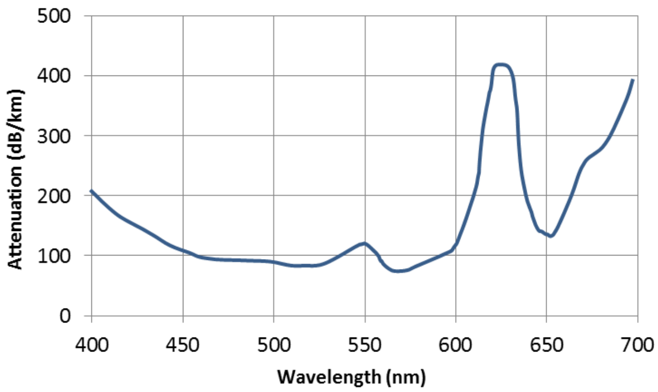

Figure 2.1.1a – The Attenuation-Wavelength curve

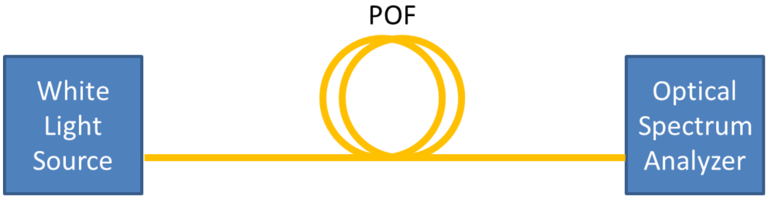

Figure 2.1.1b – Measurement setup for attenuation

2.1.2 Storage temperature range

(1) Purpose

The POF cable may be put in transit at low temperature or high temperature for a long period of time. Therefore, the POF cable needs to be maintained its characteristics even after being exposed at -40 ° C or 105 ° C for a long period of time.

(2) Procedure

1. A 50 m POF cable is put in the temperature chamber and 5 m of each end is taken out of the temperature chamber.
2. The POF cable is connected to a light source with a centre wavelength of 650 nm and an optical power meter.
3. The attenuation of the POF cable is monitored while the POF cable is continuously heated for 1000 hours at - 40 ˚C or + 105 ˚C.

(3) Requirements

Storage temperature range =- 40 °C to + 105 °C

The difference from the initial attenuation after 1000hours shall be ≤ 0.5 dB @ - 40 °C and + 105 °C

(4) Related standards

IEC 60793-1-51

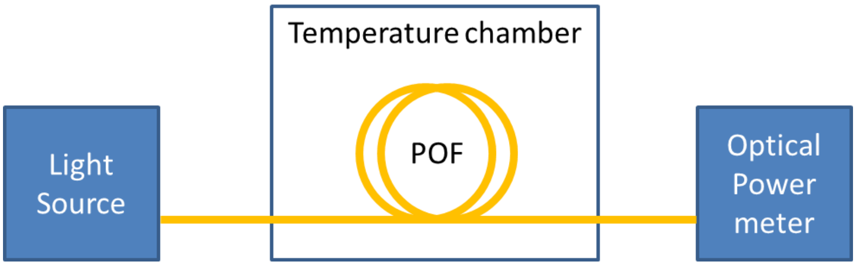

Figure 2.1.2a – Measurement setup

2.1.3 Ambient temperature range

(1) Purpose

The POF cable is installed in all the areas of a vehicle with other W/Hs.
Therefore, the POF cable needs to be maintained its characteristics under the low-temperature- and the high- temperature- environments assuming in the automotive environment.

(2) Procedure

1. A 50 m POF cable is put in the temperature chamber and 5 m of each POF-end is taken out of the temperature chamber.
2. The POF cable is connected to a light source with a centre wavelength of 650 nm and an optical power meter.
3. The attenuation of the POF cable is monitored while the POF cable is continuously heated for 1000 hours at - 40 ˚C or + 105 ˚C.

(3) Requirements

Ambient temperature range =- 40 °C to + 105 °C
The difference from the initial attenuation after 1000hours shall be ≤ 0.5 dB @ - 40 °C and + 105 °C

(4) Related standards

IEC 60793-1-51

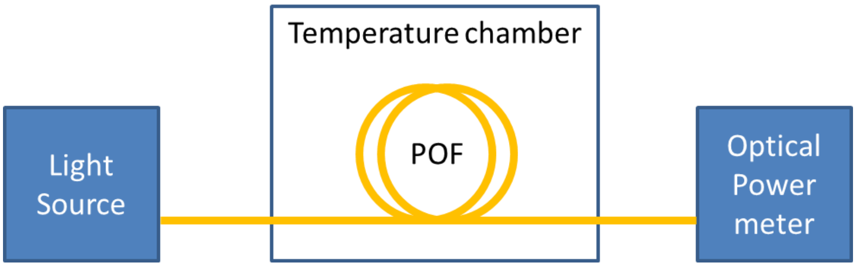

Figure 2.1.3a – Measurement setup

2.1.4 Minimum bending radius (temporary)

(1) Purpose

The POF cable may be bent slightly during the assembly process into the vehicle at a W / H factory. Therefore, it is necessary to define the minimum radius of temporary bending. The bend radius of the POF cable is defined as the distance from the centre of the bend to the jacket surface of the POF cable. The bending loss increases at the bent portion if the POF cable is squarely bent with the specified radius.

(2) Procedure

1. A 5 m POF cable is connected to a light source with a centre wavelength of 650 nm and an optical power meter. The attenuation of the POF cable is measured before bending
2. The POF cable is set at the bending jig with a 10 mm-radius and we hold it for 24 hours.
3. The POF cable is released from the bending jig for more than 1 minute and then the attenuation of POF cable is measured.
4. The temporary bending loss is calculated based on the difference of attenuation before and after bending.

(3) Requirements

Minimum bending radius (temporary) = 10 mm

Temporary bending loss in the bent portion shall be the same value of the initial value when the POF cable is released from the bending jig for more than 1 minute.

(4) Related standards

IEC 60793-1-47

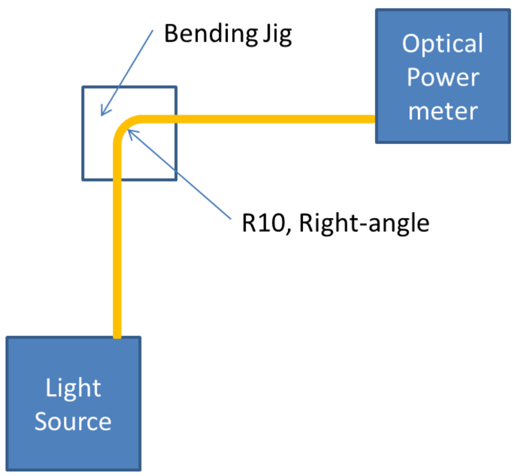

Figure 2.1.4a - Measurement setup for bending radius (temporary)

2.1.5 Minimum bending radius (permanent)

(1) Purpose

The increase of permanent loss in the bent portion is included in the transmission loss of the optical harness, because the structural design of the bent portion is fixed by the optical wire harness design. The POF cables have to keep the low bending loss in their W/H condition. The bending loss increases at the bent portion when the POF cable is squarely bent with the specified radius. The bend radius of the POF cable is defined as the distance from the centre of the bend to the jacket surface of the POF cable.

(2) Procedure

1. A 5 m POF cable is connected to a light source with a centre wavelength of 650 nm and an optical power meter.
2. The attenuation of the POF cable is measured before bending.
3. The POF cable is bent to 90 degrees using a jig. The bending position is 1 m from the light source.
4. The POF cable is bent for 1 minute and then the attenuation is measured. The bending loss is calculated based on the difference of attenuation before and after bending.

(3) Requirements

Minimum bending radius (permanent) = 25 mm
Bending loss ≤ 0.5 dB @ R 25 mm

(4) Related standards

IEC 60793-1-47

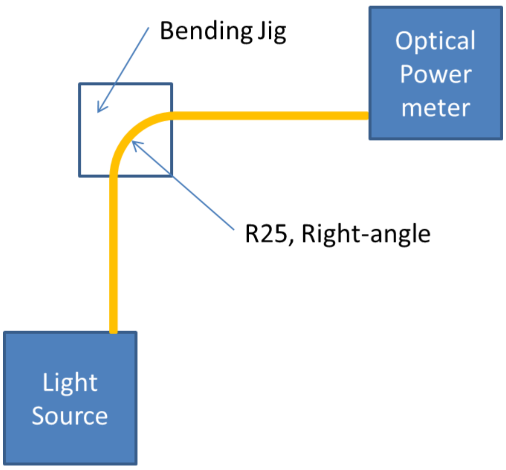

Figure 2.1.5a - Measurement setup for bending radius (permanent)

2.1.6 Minimum tensile strength

(1) Purpose

The optical W/H may be pulled during the assembly process into the vehicle or the maintenance. Therefore, the POF cable needs to be withstood when operators pull it

(2) Procedure

It is necessary to measure pulling strength of the POF cable with the single core cable-form. It is difficult to clamp the POF cable ends, because the surface of the general jacket materials has a low friction characteristic. In this case, the special clamp-jig (clamp with wire-wrapping, etc.) will be needed.

1. The tensile strength tester is set up for the POF cable.
   The POF is fixed with a length of 100 to 200 mm on both sides by zipper.
2. Pulling-speed is based on the provided conditions.

(3) Requirements

Tensile strength for 5 % elongation ≥ 60N for simplex @ pulling speed of 100 mm/min

(4) Related standards

IEC 60794-1-21
IEC 60794-2-41

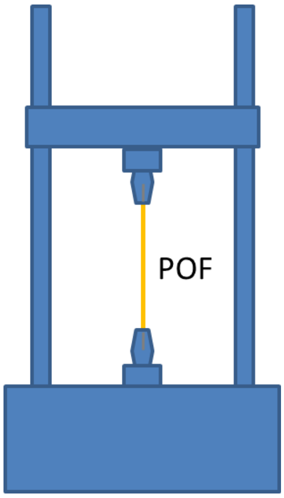

Figure 2.1.6a - Measurement setup for tensile strength

2.2 Mechanical/Optical properties for connector

2.2.1 Materials

Materials used for manufacturing header connectors integrated with FOTs must be capable of withstanding typical industry soldering processes. Thermoplastic materials used for the connectors and cables shall have a flammability rating of “HB” according to UL 94 or IEC 60695-11-10.

The properties of all connector and cable materials shall not been affected by:

*Automotive fluids (engine coolants, transmission fluid, brake fluid, windshield washer fluid, alcohol- based fuels, diesel fuels, etc.) and

*Commercial fluids (coffee, cola, alcohol and ammonia- based cleaners, hand lotion, etc.)

2.2.2 Storage temperature range

(1) Purpose

The optical connector may be put in transit at low temperature or high temperature for a long time of period. Therefore, the optical connector needs to be maintained its characteristics even after being exposed at -40 ° C or 105 ° C for a long time of period.

(2) Procedure

1. The dimensions of the connectors are measured.
2. The cable plug and the cable socket are put into the temperature chamber.
   The temperature chamber is set up at 105 ° C or -40 ° C.
3. The cable plug and the cable socket are taken out of the temperature chamber after 1000 hours and we hold them at room temperature for 24 hours.
4. The dimensions of the connectors are measured in the same procedure as the measurement before the test.

(3) Requirements

- 40 °C to 105 °C

There is no change in dimensions before and after the test, and no external abnormality is confirmed.

(4) Related standards

ISO 8092-2
EIA/TIA 455-13A

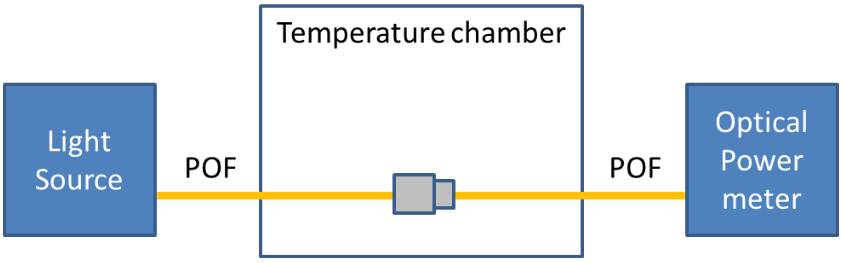

Figure 2.2.2a – Measurement setup

2.2.3 Maximum coupling loss

(1) Purpose

It is known that coupling loss occurs when optical fibres are connected with each other. Therefore, the maximum coupling loss of inline connectors shall be defined to maintain the total permissible attenuation for optical W/Hs.

(2) Procedure

1. A POF cable without an inline connector is prepared, and its transmission loss is measured (A).
2. The POF cable is cut, and the inline connectors (plug and socket) are assembled at both the POF-ends
3. The inline connectors are mated, and the transmission loss of the POF cable with inline connectors is measured (B).
4. The difference between the obtained transmission loss (B) and the transmission loss (A) of the POF cable without inline connectors is the coupling loss of inline connectors.

(3) Requirements

Coupling loss ≤ 1.5 dB

(4) Related standards

EIA/TIA 455-34A

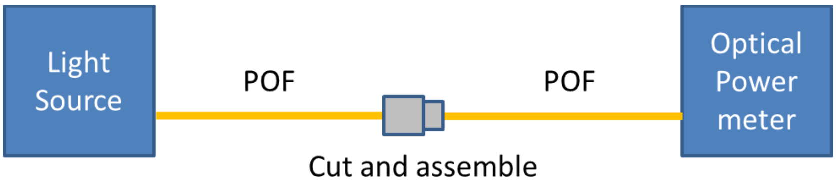

Figure 2.2.3a - Measurement setup for coupling loss

2.2.4 Minimum lock strength

(1) Purpose

The optical W/H might be pulled during the assembly process into the vehicle or the maintenance

Therefore, the optical connector needs to be withstood when operators pull it.

(2) Procedure

1. A pair of inline connectors (plug and socket) and 2 POF cables are prepared.
2. The plug and the socket are assembled at each POF-end.
3. Inline connectors are mated and locked.
4. DUT is clamped by the tension tester, as shown in Figure 2.2.5a.
5. Pulling-speed is based on the provided conditions.

(3) Requirements

Lock strength ≥ 100 N @ pulling speed of 50 mm/min

(4) Related standards

ISO 8092

ANSI/EIA 364-13

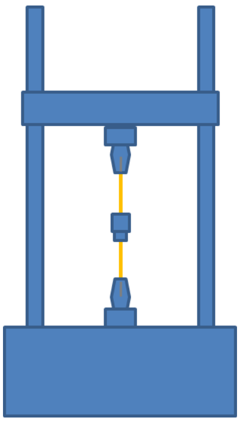

Figure 2.2.4a - Measurement setup for lock strength

2.2.5 Minimum cable holding force

(1) Purpose
The optical W/H may be pulled during the assembly process into the vehicle or the maintenance. Therefore, the POF connector needs to be withstood when operators pull it.

(2) Procedure
1. The plug or the socket with the POF cable is fixed at the lower part of the clamp of the tensile strength tester.
2. The POF cable is fixed at the upper part of the clamp of the tensile strength tester.
3. Pulling-speed is based on the provided conditions.
4. The cable retention force of the cable socket is measured in the same manner.

(3) Requirements
Cable holding force ≥ 110 N@ pulling speed of 50 mm/min

(4) Related standards
EIA 364-38A-83

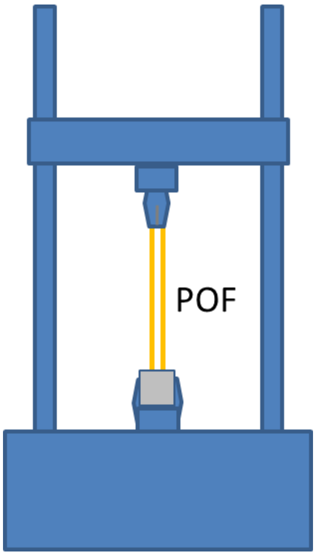

Figure 2.2.5a - Measurement setup for cable retention force

2.2.6 Maximum mating force

(1) Purpose

It is required to reduce the connector mating force during assembling W / Hs into vehicles.

(2) Procedure

1. The inline connectors (cable plug and cable socket) are set at the pre-lock position.
2. DUT is set at the Push/Pull tester, as shown in the figure below.
3. Both connector housings are pushed by the tester.
4. The head-speed etc. of the Push/Pull tester are based on the provided conditions.

(3) Requirements

Insertion force ≤ 45 N @ push speed of 50 mm/min

(4) Related standards

ISO 8092-2 Part.4.3
ANSI/EIA 364-13

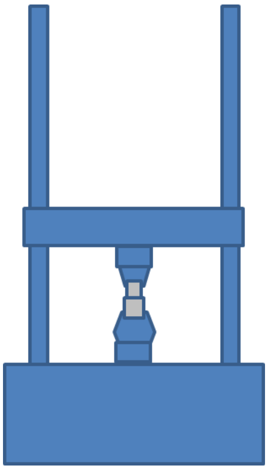

Figure 2.2.6a - Measurement setup for mating force

2.2.7 Mating tolerance

(1) Purpose

The W/H connector is mated/unmated several times during the product inspection and the maintenance. The POF cables have to keep the optical power in their W/H condition. Therefore, it is required that optical characteristics do not change even when mated / unmated is repeated.

(2) Procedure

1. The transmission loss of fibre optic cable with one inline connector is measured.
2. Fibre optic cable should not be moved during the mate/unmate cycle test of inline.
3. After mate/unmate cycle-test with provided cycles.
4. The coupling loss changing from the initial value is measured.

(3) Requirements

Mate/unmate cycles = 10 times
The coupling loss changing from the initial value ≤ 0.5dB after mate/unmate cycles

(4) Related standards

IEC 60512-13-2

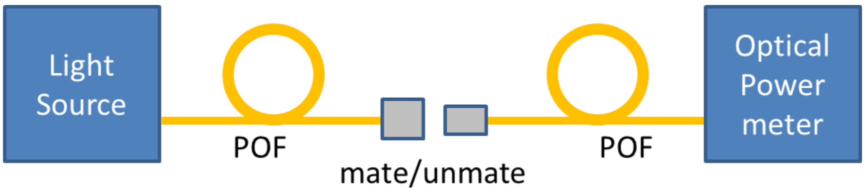

Figure 2.2.7a - Measurement setup for mating tolerance

3 Electrical properties

3.1 Power consumption (active)

3.1.1 PHY

Definition of "link is established" according to 802.3bv D2.0 Section 114.3.7.1, the PHY quality criterion to consider reliable payload data reception is the BCH Frame Error Rate (BFER) is less than 8.8×10^{-11} after BCH decoding. This condition is reported by the PHY by means of variable loc_rcvr_status, reflected in the MDIO register 3.519.15, according to 802.3 section 45.2.3.51. Sections 114.3.7.3 and 114.3.7.4 of 802.3bv D2.0 provide formal specification of the state diagram in charge to determine the value of loc_rcvr_status. According this state diagram, the value of this variable is sent to the link partner in the PHD field PHD.RX.LINKSTATUS. Reception of this field by link monitor state diagram specified in sections 114.3.5.1 and 114.3.5.4, determines the quality of remote PHY data reception. Remote PHY receiver status is reflected in the MDIO register 3.519.14. When reception is reliable for both link partners, the link is established. Link status is reflected in MDIO register 3.519.13 and always indicates bidirectional reliable operation.

The power consumption of a complete PHY (PCS, PMA plus PMD) shall be less than 800 mW under any operation condition (voltage and temperature conditions).

3.1.2 FOT

The maximal power consumption of the FOT is 260 mW (assuming a DC voltage supply of 3.3 V ± 5 %).

Basically, the power consumption is a calculated quantity and can be obtained by applying a DC supply voltage (3.3 V ± 5 %) for both Tx and Rx, gigabit Ethernet data (electrically at the transmitter and optically at the receiver) and valid DC enable signals for both Tx and Rx to measure the total current consumption of the transceiver. This current value must be multiplied with the maximum supply voltage (3.3 V + 5 %) to get the maximum power consumption.

3.2 Dependability parameters monitored and reported by the PHY

Local and remote link margin parameters shall be used by the ECUs for link dependability purposes.

According to 802.3bv D2.0 114.3.7.2 to 114.3.7.4, the local PHY estimates the link margin of the received signal. The local link margin is reported to the link partner by using the field PHD.RX.LINKMARGIN in the transmitted PHD. The link margin is defined as the SNR margin relative to the SNR required for reception of coded PAM16 with a quality per specification of 114.3.7.1. In this way, the received PHD.RX.LINKMARGIN corresponds to the link margin of the remote PHY.

Both, local and remote link margins are reflected by a PHY in the MDIO registers 3.520 and 3.521, respectively. Content and format of theses registers are specified in 802.3bv D2.0 45.2.3.52, 45.2.3.52, 114.2.7.2 and 114.3.8.

4 Timing properties

4.1 Link acquisition time (PHY to PHY link start up time)

The time to establish the link (see bullet above for definition of link establishment) needed by a couple of 1000BASE-RHC PHYs shall be less than 100 ms (milliseconds) under any operation condition. The link establishment time shall be measured from stable supply voltages are provided to both PHYs. Same specification shall be fulfilled in case of transition from sleep to active state when Wake-Up Pulse (WUP) is detected.