

## 8. Alternative low cost long distance physical media dependent layers

The alternative low cost long distance physical layers specified by this section enable distance extension over 50m keeping interoperability with existing IEEE1394-1995 interface as well as in-progress interface of P1394.a at the data rate of 100Mbps, 200Mbps and 400Mbps. The remarks below apply to external cabling and interface, where extra care must be exercised for safety and EMC compliance.

### 8.1 Plastic Optical Fiber and Hard Polymer Clad Fiber Links with 650nm Light Emitting Diode

#### 8.1.1 Scope

This clause specifies the physical media dependent (PMD) sublayer of Plastic Optical Fiber (POF) and Hard Polymer Clad Fiber (HPCF) links with 650nm light emitting diode (LED) for the data rate of 100Mbps and 200Mbps. This PMD provides the very low cost digital baseband point-to-point interconnection among IEEE1394 equipments for the distance extension over 50m, which meet a requirement criteria of IEEE1394 long distance link. HPCF link provides longer distance transmission capability up to 100m, POF link supports 50m minimum transmission distance though. The PMD shall provide all of the services required to transport a suitably coded digital bit stream across the link segment.

The PMD sublayer specified in this clause has the following general characteristics:

- Provides a means of converting the IEEE1394-1995 physical layer or in-progress physical layer of P1394.a to the POF and HPCF link segment by way of the Active Interface.
- Provides a means of transmitting and receiving the optical signal between two active optical interfaces.
- Provides a common optical interface for POF and HPCF at each baud rate.
- Provides 100Mbps / 200Mbps dual mode capability for interconnecting 200Mbps interface to 100Mbps interface over common optical cable and connectors during a startup mode.

#### 8.1.2 Glossary of Terms

- 30) BER - Bit Error Ratio
- 31) FWHM - Full Width Half Maximum
- 32) HPCF - Hard Polymer Clad Fiber
- 33) LED - Light Emitting Diode
- 34) NA - Numerical Aperture
- 35) POF - Plastic Optical Fiber

#### 8.1.3 Cables

The POF shall be 1000  $\mu$ m step index multimode plastic optical fiber. The HPCF shall be 225  $\mu$ m graded index multimode hard polymer clad fiber.

POF shall have a minimum modal bandwidth of 10 MHz\*km at 650 nm when measured in accordance with IEC 793-1-C2A or IEC 793-1-C2B. HPCF shall have a minimum modal bandwidth of 25MHz\*km at 650 nm when measured in accordance with IEC 793-1-C2A or IEC 793-1-C2B. The specifications for fiber modal bandwidth include a variation in source numerical aperture and account for the effect of bandwidth degradation to ensure correct system operation.

The maximum attenuation of 50 m POF under the condition of -20 to +70 degrees C and 95% relative humidity shall be 9.1 dB. The maximum attenuation of 100 m HPCF under the condition of -20 to +70 degrees C and 95% relative humidity shall be ~~2.7~~ 2.6 dB. The attenuation shall be measured in accordance with IEC 793-1-C1A or C1B using a nominal 650 nm narrow (< 5 nm FWHM) spectral width light source.

In addition, the fiber loss due to environmental conditions and launch NA is included in the attenuation of 9.1 dB for POF and ~~2.7~~ 2.6 dB for HPCF. The loss increments of 3.4 dB for POF and 0.1 dB for HPCF, shown in table 8-1, account for both a source center wavelength shift to 660 nm or 640 nm and the difference between the < 5 nm spectral width of the test source and 40 nm worst case source spectral width. Loss increments of 0.5 dB for POF and 0.1 dB for HPCF due to cable bends are also accounted for as shown in table 8-1.

For the condition shown in table 8-1, the worst case fiber attenuation for 50 m POF shall be 13 dB and the worst case fiber attenuation for 100 m HPCF shall be ~~2.9~~ 2.8 dB.

**Table 8-1— Worst case loss increments for 50m POF cable and 100m HPCF cable**

Parameters	Unit	Minimum	Maximum	Loss Increment
Source center wavelength	nm	640	660	POF: 3.4dB
Source spectral width (FWHM)	nm		40	HPCF: 0.1dB
Cable bend radius	mm	25.4		POF: 0.5dB HPCF: 0.1dB

### 8.1.4 Connectors

(TBD)

### 8.1.5 Connector and cable assembly performance criteria

The worst case connector insertion loss, including the effect of environmental conditions, shall be less than 2.0 dB for POF and ~~1.4~~ 1.3 dB for HPCF.

### 8.1.6 Optical Fiber Interface

This section specifies a Physical Media Dependent (PMD) sublayer over plastic optical fiber (POF) and hard polymer clad fiber (HPCF) using light emitting diodes (LEDs) operating at nominal baudrate of 125MBaud and 250MBaud. The POF interface is intended for link lengths of up to 50 m. The HPCF interface is intended for link lengths of up to 100 m.

The optical line coding is binary NRZ. Binary 1 shall be represented as a high light level condition.

An interface receiver shall operate with a bit error ratio (BER) not to exceed  $10^{-12}$  (1 bit error in  $10^{12}$  bits) when presented with a transmitter signal as specified in table 8-2 and 8-3 transmitted through a link subject to the system budget constraints specified as follows.

Proper system performance is ensured by considering the attenuation and modal bandwidth of the optical path and including them as part of the link budget. In addition to these cable plant characteristics, a system power penalty is normally included in the link budget. The power penalty includes the effects of eye closure due to transmitter characteristics (finite rise and fall times, random and systematic jitter). This system power penalty is accounted for in the receiver sensitivity specification; therefore, the system budget is composed entirely of losses due to the cable plant and connectors.

The attenuation range specification for the links were defined based on the use of components meeting the requirements specified in 8.1.3 and operating up to 50 meters for POF and up to 100 meters for HPCF. The static attenuation in the optical path includes worst case loss values for the fiber media and connectors. The attenuation range for POF link is 13dB, of which 13 dB is allocated for 50m fiber. The attenuation range for HPCF link is 4.0dB, of which ~~2.9~~ 2.8 dB is allocated for 100m fiber. Both of attenuation ranges are independent of baudrate. The allowable connection number and transmission length have a trade-off as summarized in table 8-4 of Annex-A.

The values prescribed in table 8-2 and table 8-3 are for worst case operating conditions and end of life; they are to be met over the full range of standard operating conditions, (i.e., voltage, temperature and humidity) and include aging effects. The following parameters are specified for the transmitter and receiver. 250MBaud interface is specified to have a capability of interconnection with 125MBaud interface during the startup mode.

**Table 8-2—Optical Parameters for POF and HPCF Interfaces at 125MBaud**

	POF	HPCF	Unit
<b>Transmitter Interface Characteristics</b>			
Center Wavelength (FWHM)	640 to 660	640 to 660	nm
Maximum Spectral Width (FWHM)	40	40	nm
Mean Launched Power (Note1)	-8 to -2	-20 to -14	dBm
Source NA	0.2 to 0.3	0.2 to 0.3	
Minimum Extinction Ratio	10	10	dB
Maximum Rise (Fall) Time, (10-90%)	4.5	4.5	ns
Maximum Overshoot	25	25	%
Maximum Systematic Interface Jitter	1.6	1.6	ns
Maximum Romdom Interface Jitter	0.6	0.6	ns
<b>Receiver Interface Characteristics</b>			
Minimum Receiver Input Power (Note2)	-21	-24	dBm
Minimum Overload	-2	-14	dBm
Maximum Rise (Fall) Time, (10-90%)	5.0	5.0	ns
Maximum Systematic Interface Jitter	1.6	1.6	ns
Maximum Random Interface Jitter	0.6	0.6	ns
Minimum Receiver Eye Opening (Note3)	1.5	1.5	ns

NOTE 1—The interface specifications for both POF and HPCF fibers are based on the use of a common optical transmitter and receiver. Differences in the optical power level between HPCF and POF link specifications are due to the fiber core diameter and NA. The interface point for the mean launched power specification is a short length of fiber (e.g. 50 cm) located immediately after the plug of the connector attached to the transmitter receptacle. The connector at this interface point is therefore considered to be part of the equipment and not part of the cable plant.

NOTE 2—The improved minimum receiver input power for the HPCF receiver interface is due to the more efficient optical coupling from the smaller diameter HPCF into the same optical detector to achieve a minimum detected current. The interface point for the minimum receiver input power specification is located between the plug of the connector and the receptacle.

NOTE 3—The receiver eye opening represents the time interval allocated for the clock recovery function after the optical to electrical conversion at the receiver.

**Table 8-3—Optical Parameters for POF and HPCF Interfaces at 250MBaud**

	POF	HPCF	Unit
<b>Transmitter Interface Characteristics</b>			
Center Wavelength (FWHM)	640 to 660	640 to 660	nm
Maximum Spectral Width (FWHM)	40	40	nm
Mean Launched Power (Note 4)	-8 to -2	-20 to -14	dBm
Source NA	0.2 to 0.3	0.2 to 0.3	
Minimum Extinction Ratio	10	10	dB
Maximum Rise (Fall) Time, (10-90%)	3.0	3.0	ns
Maximum Overshoot	25	25	%
Maximum Systematic Interface Jitter	0.8	0.8	ns
Maximum Random Interface Jitter	0.3	0.3	ns
<b>Receiver Interface Characteristics</b>			
Minimum Receiver Input Power (Note 5)	-21	-24	dBm
Minimum Overload	-2	-14	dBm
Maximum Rise (Fall) Time, (10-90%)	3.5	3.5	ns
Maximum Systematic Interface Jitter	0.8	0.8	ns
Maximum Random Interface Jitter	0.3	0.3	ns
Minimum Receiver Eye Opening (Note 6)	0.8	0.8	ns

NOTE 4—The interface specifications for both POF and HPCF fibers are based on the use of a common optical transmitter and receiver. Differences in the optical power level between HPCF and POF link specifications are due to the fiber core diameter and NA. The interface point for the mean launched power specification is a short length of fiber (e.g. 50 cm) located immediately after the plug of the connector attached to the transmitter receptacle. The connector at this interface point is therefore considered to be part of the equipment and not part of the cable plant.

NOTE 5—The improved minimum receiver input power for the HPCF receiver interface is due to the more efficient optical coupling from the smaller diameter HPCF into the same optical detector to achieve a minimum detected current. The interface point for the minimum receiver input power specification is located between the plug of the connector and the receptacle.

NOTE 6—The receiver eye opening represents the time interval allocated for the clock recovery function after the optical to electrical conversion at the receiver.

## 8.2 Annex-A

(informative)

### Allowance of connection number

The maximum transmission distance depends on the number of fiber to fiber connection point on the cable plant. Table 8-4 summarizes the trade-off based on worst case component attenuation as specified in section 8.1.3, 8.1.5 and 8.1.6.

**Table 8-4—Trade off for the number of connection and transmission length**

No. of connection	Length of POF link (m)	Length of HPCF link (m)
0	50	100
1	42	<del>100</del> <u>96</u>
2	34	<del>60</del> <u>50</u>
3	27	<del>21</del> <u>4</u>